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METRO TORONTO & REGION REMEDIAL ACTION PLAN

METROPOLITAN TORONTO WATERFRONT WET WEATHER OUTFALL STUDY - PHASE II CITY OF TORONTO

Remedial Action Plan
Plan d'Assainissement

Canada Ontario

COVER IMAGE SHOWING THE METROPOLITAN TORONTO WATERFRONT:
Scanned from the LANDSAT Thematic Mapper False Colour Infrared Image (1990 09 02), archive of the Provincial Remote Sensing Office, Ministry of Natural Resources.
Vegetation appears in shades of red. Bare soil and pavement appears in shades of turquoise.

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CITY OF TORONTO

AUGUST 1995

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METROPOLITAN TORONTO WATERFRONT

WET WEATHER OUTFALL STUDY -- PHASE II

CITY OF TORONTO

Report prepared for:

The Metropolitan Toronto and Region Remedial Action Plan

by

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FOREWORD

This report has been prepared under the auspices of the Canada-Ontario Great Lakes Remedial Action Plan Program. Financial support for the study was provided by Environment Canada and the Ontario Ministry of Environment and Energy.

The Canada-Ontario Remedial Action Plan Steering Committee has reviewed this report and approved its publication. Approval does not necessarily signify that the contents reflect the views and policies of individual agencies, nor does mention of trade names or commercial products constitute endorsement or recommendatation for use.

This report is part of a series of technical investigations conducted in support of the Metropolitan Toronto and Region Remedial Action Plan (RAP). For additional technical reports or information on the RAP, contact the Metropolitan Toronto and Region RAP Coordinator at:

Ontario Ministry of Environment and Energy
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J. Minor	City of Scarborough

EXECUTIVE SUMMARY

In support of the continued development of the Metropolitan Toronto and Region Remedial Action Plan, this report presents a summary of wet weather discharges along the City of Toronto waterfront. The sources addressed in this study consist of wet weather discharges to the waterfront from: 29 outfalls which receive storm water from areas serviced by separated storm sewers, 24 outfalls which receive combined sewer overflows (CSOs) and the bypass of primary effluent from the Metro Main Water Pollution Control Plant. As shown in Figure 1, the study area encompassed the City of Toronto waterfront between the Humber River and Victoria Park Avenue. This stretch of the waterfront consists of four regions, identified from west to east as: the Western Beaches, Toronto Inner Harbour, Ashbridges Bay and the Eastern Beaches.

The study, initiated in 1990, involved the collection of flow and water quality data from representative sites, compiling water quality data to determine contaminant concentration characteristics, applying an urban runoff prediction model for the estimation of volumetric discharges for each outfall and estimating seasonal contaminant mass loadings for each outfall. Water quality samples were analyzed for a comprehensive list of parameters which included general water chemistry, bacteriology, nutrients, heavy metals and trace organic compounds. A special emphasis was placed on the analysis of trace organic priority pollutants including PCBs, polycylic aromatic hydrocarbons, chlorobenzenes and organochlorine pesticides. This involved the collection of large volume samples and the use of special analytical techniques which provided detection limits about one order of magnitude lower than traditional techniques.

Many of the chemical data sets contained data at or below the analytical detection limit. Non-traditional statistical techniques such as the Maximum Likelihood Estimator were used to generate statistical summaries for these data sets.

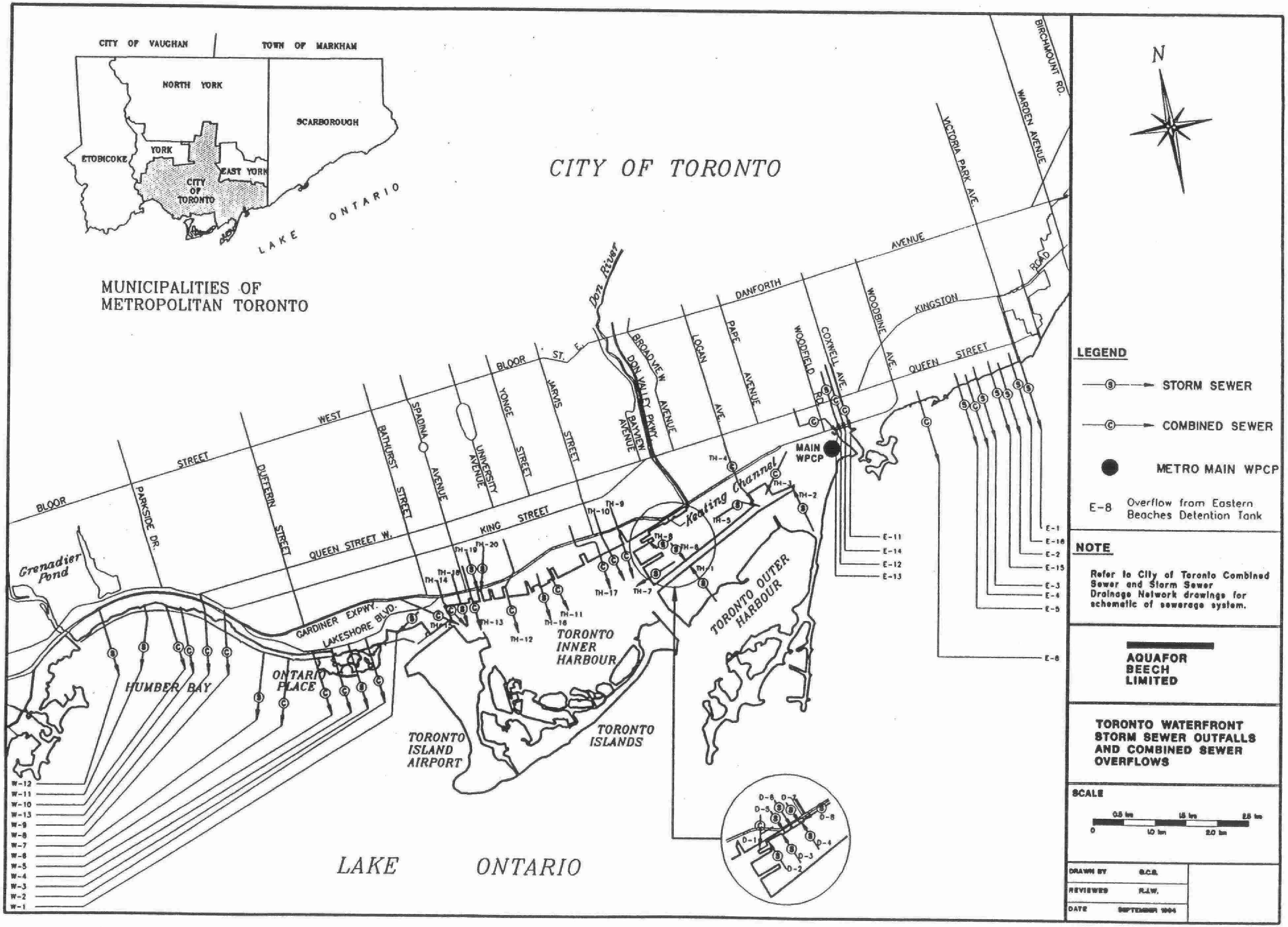


FIGURE 1 WET WEATHER DISCHARGES TO THE CITY OF TORONTO WATERFRONT

Summaries of contaminant detection frequencies, mean concentrations and contaminant mass loadings are presented by outfall type. The mean chemical concentrations for selected parameters are also presented graphically by outfall type. A summary of mean contaminant concentrations by outfall type is presented in Figure 2 for representative parameters. A measure of variability associated with each estimate is represented by the 95% confidence interval, wherever possible. Where applicable, the mean contaminant concentrations are compared to Provincial Water Quality Objectives/Guidelines (PWQO/Gs) and the Metro Toronto Sewer Use Bylaw. While PWQO/Gs have been derived as receiving water based standards for the protection of aquatic life and recreational uses of water, they also provide a benchmark by which the significance of a discharge can be gauged.

Similarly, estimates of contaminant mass loadings are presented graphically by outfall type and region of the waterfront. A graphical summary of contaminant mass loadings by outfall type and region is presented for representative parameters in Figures 3 and 4, respectively.

The following summarizes the major statements derived from this study:

Flow Characteristics

- Seasonal (May 1 through October 31) runoff volumes were obtained through computer simulations by the City of Toronto Department of Works and the Environment using the Dorsch Quantity-Quality Simulation (QQS) Model. The predictions were based on the 1980 rainfall distribution which was determined to be representative of historical average conditions for characteristics such as seasonal and event rainfall depth, event duration, event intensity and number of events. Plant data was used to estimate seasonal discharges from the Metro Main WPCP bypass.

- The applicability of the QQS Model predictions for the estimation of volumetric discharges from sewer outfalls was evaluated through comparisons with field

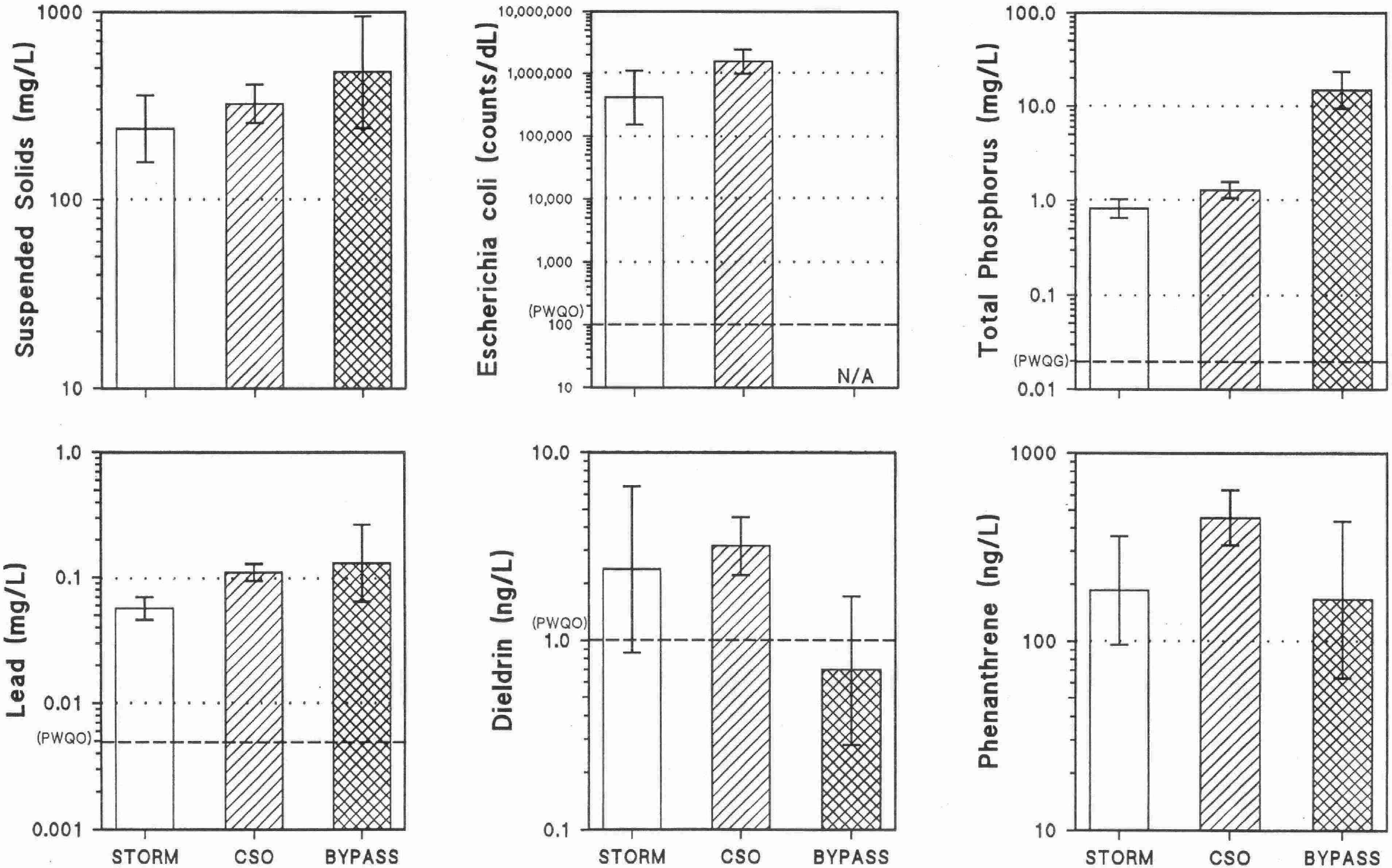


FIGURE 2 MEAN CONTAMINANT CONCENTRATIONS WITH THE 95% CONFIDENCE INTERVAL FOR REPRESENTATIVE PARAMETERS

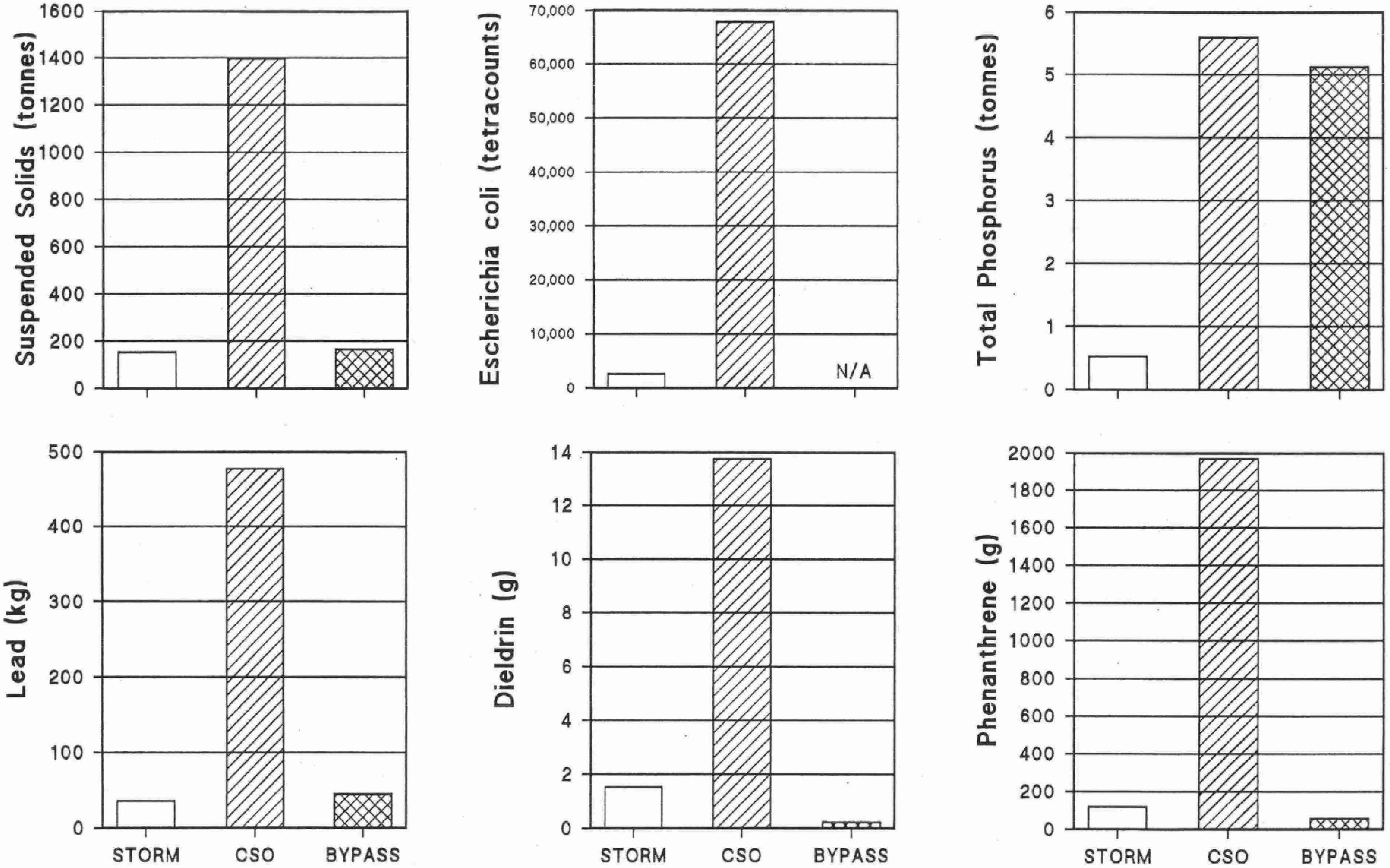


FIGURE 3 MEAN SEASONAL (May to October) CONTAMINANT MASS LOADINGS BY OUTFALL TYPE FOR REPRESENTATIVE PARAMETERS

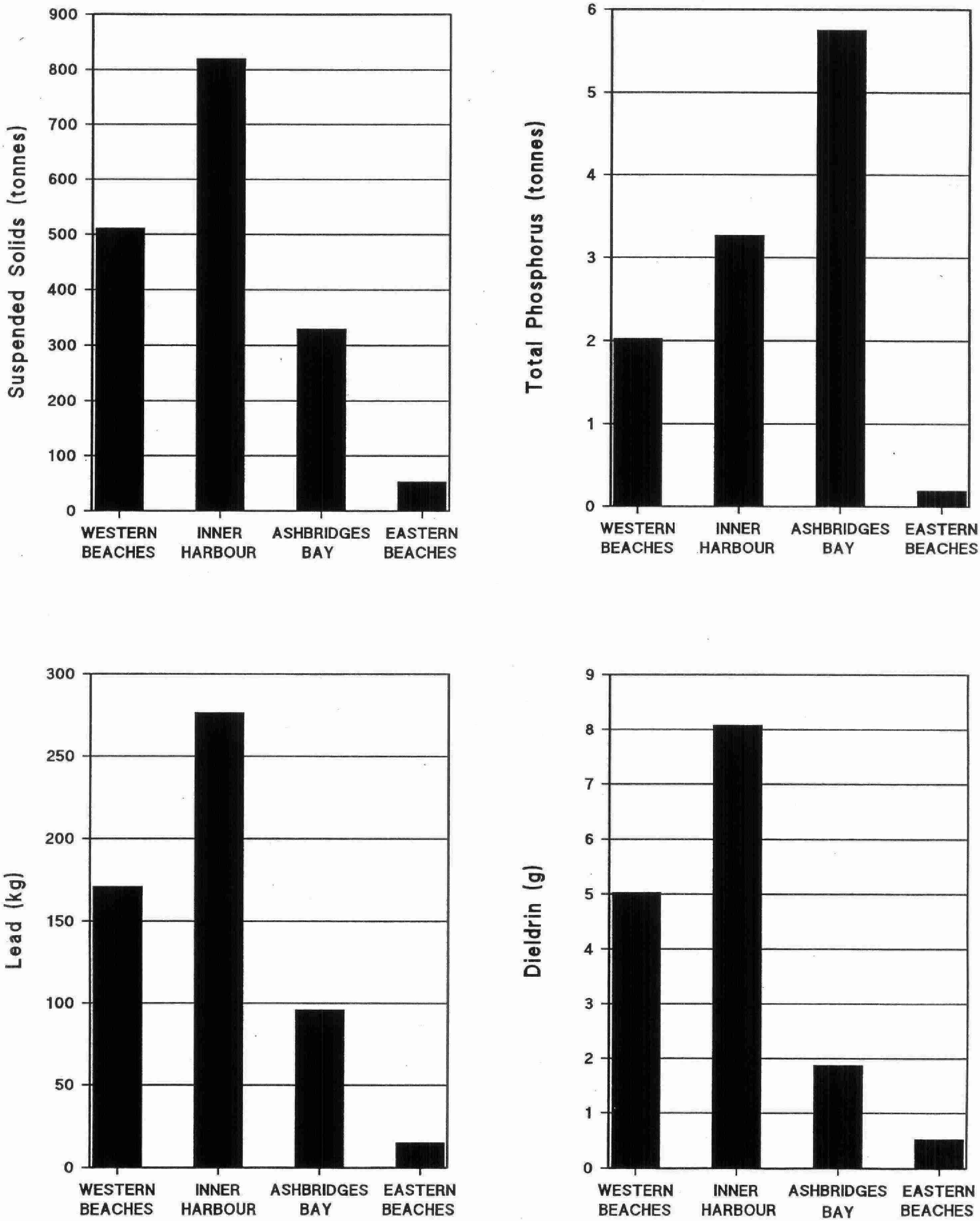


FIGURE 4 MEAN SEASONAL (May to October) CONTAMINANT MASS LOADINGS BY REGION FOR REPRESENTATIVE PARAMETERS

measured flow data collected at several sites in this study. Generally, the predicted runoff volumes were found to be within 20 percent of the field measurements.

- The total seasonal (May 1 to October 31) flow volume from outfalls discharging to the City of Toronto waterfront was estimated to be about 5.3 million cubic meters, which includes 0.3 million cubic meters discharged as bypass of primary effluent from the Metro Main WPCP.

- Geographically, about 48% of the total wet weather flow is discharged to the Toronto Inner Harbour, 31% to the Western Beaches, 17% to Ashbridges Bay and 4% to the Eastern Beaches.

- By outfall type, about 81% of the total wet weather flow is discharged from outfalls which receive combined sewer overflows, 12% from outfalls which receive storm water from separated storm sewers and about 7% from the bypass at the Metro Main WPCP.

- Approximately 56% of the total flow volume is discharged by five sewer outfalls which receive CSOs and the Metro Main WPCP bypass. These discharges are identified with their corresponding relative flow contribution as: TH14 (14%), TH15 (13%), W13 (10%), W2 (7%), Metro Main WPCP bypass (7%) and E11 (5%).

<u>Compilation of Contaminant Database</u>

- Low level detection techniques used in the analysis of trace organic compounds improved the analytical detection limit by a factor of 10 over traditional methods. This resulted in the identification of more priority pollutants and produced higher detection frequencies than reported in previous studies.

- A list of parameters with relatively high detection frequencies has been compiled. The list includes parameters from the following organic contaminant groupings: chlorobenzenes, organochlorine pesticides, and polynuclear aromatic hydrocarbons.

- Parameters where discharge concentrations are generally in exceedance of applicable receiving water criteria have also been identified for consideration in future regulatory monitoring programs.

- Many toxic parameters found at high frequencies of detection have also been identified by MOEE as candidate substances for bans or phase-outs.

Contaminant Concentration Characteristics

- The statistical relationship between the event mean concentration (EMC) and runoff volumes was evaluated. In general, the EMCs were found to be independent of runoff volume and no significant relationships were identified using linear regression analysis. However, for large events in which significant overflow volumes occurred, data collected at one CSO site (outfall W5) showed that when presented graphically, event mean concentrations for conventional parameters (eg. suspended solids, nutrients and heavy metals) appeared to increase linearly with runoff volume.

- In comparison to storm sewer discharges, average event mean contaminant concentrations measured in discharges from outfalls receiving combined sewer overflows were found to be similar for most parameters. However, significantly higher concentrations were measured in CSO discharges for total phosphorus, most heavy metals, and a few trace organic compounds such as PCBs, lindane, pp-DDD, benzo (b) fluoranthene and chrysene.

- In comparison to sewer discharges, average event mean contaminant concentrations

measured at the Metro Main WPCP bypass were significantly higher for nutrients, phenolics and most heavy metals. Concentrations of trace organic compounds were generally similar to those measured in sewer outfalls.

- Average event mean concentrations for all discharges considered in this study were generally in exceedance of Provincial Water Quality Objectives/Guidelines for general chemistry parameters, bacteria and heavy metals. With the exception of dieldrin and PCBs, concentrations of trace organic compounds, which have applicable provincial water quality criteria, were generally lower than Provincial Water Quality Objectives.

- While concentrations of trace organic compounds were generally lower than Provincial Objectives, these and many other parameters for which objectives are not available were found at high frequencies of detection, and have been identified by the Ontario Ministry of Environment and Energy as candidate substances for bans or phaseouts.

Comparison of Contaminant Mass Discharges

- Contaminant mass loadings have been presented by outfall type and geographic region. Contaminant mass loadings for sources considered in this study are highly dependent on flow volume discharge because, for many parameters, concentrations measured in each source are similar.

- Consistent with estimates of flow volumes discharged, contaminant mass loadings from CSO outfalls are generally an order of magnitude higher than those estimated for discharges from storm sewers and the Metro Main WPCP bypass. Similarly, contaminant mass loadings to Toronto Inner Harbour are generally higher than the other three regions (Western Beaches, Ashbridges Bay and Eastern Beaches).

- While the combined volumetric discharge from CSO outfalls was estimated to exceed the discharge from the Metro Main bypass by a factor of 12, contaminant mass loadings from the bypass were found to be similar or exceed CSOs for several parameters including ammonia, total phosphorus, phenolics, cadmium, chromium and silver.

- On a regional basis, estimates of contaminant mass loadings are generally higher for the Inner Harbour followed by the Western Beaches, Ashbridges Bay and the Eastern Beaches. Loadings to the Eastern Beaches are typically an order of magnitude lower than the other regions. Contaminant mass loadings to the Inner Harbour are typically 40 to 60 percent of the total estimated loadings. However, because of significant contributions from the Metro Main bypass, loadings to the Ashbridges Bay area are higher for nutrients, phenolics and some heavy metals.

The distribution of flow volumes and contaminant mass loadings as reported by outfall type and geographic region is continuing to change as a result of ongoing improvements to the City of Toronto sewer system. For example, since initiating this study, the Phase II Eastern Beaches Detention Tank has been constructed and will result in a reduction of flow volumes and contaminant loadings to the Eastern Beaches, and a reduction of contaminant loadings from storm sewers and combined sewer overflows to the waterfront.

Contaminant mass loadings presented in this report represent the seasonal contribution for the period May 1 to October 31. A previous RAP study suggested that these seasonal estimates may represent only about one third of the total annual loading. Consequently, a separate study is being conducted to evaluate seasonal differences in chemical concentrations, discharge flow volumes and contaminant mass loadings.

It should be emphasized that while this report presents a comprehensive analysis of direct wet weather discharges to the City of Toronto waterfront, a comparison between all sources discharging to the waterfront requires consideration of all contaminant discharges including

area tributaries. This analysis is being conducted through a separate RAP study.

In addition, while the contaminant concentration and mass loading data presented in this report provides an indication of the potential impact on the nearshore aquatic environment, the degree of actual impact will depend on site specific conditions which include outfall configuration, discharge flow rate, shoreline geometry, lake bathymetry, lake stratification, lake circulation patterns and the cumulative effect of all waterfront discharges. This can be assessed through computer simulation and a project directed at developing a numerical model to provide water quality and water circulation patterns along the waterfront, has been initiated jointly by the Ontario Ministry of Environment and Energy, Environment Canada, the Municipality of Metropolitan Toronto and the waterfront cities of Etobicoke, Toronto and Scarborough. Once completed, the model will be used to assess the relative impact of all waterfront discharges on the near shore aquatic environment, evaluate options to mitigate the impact of these discharges and assist in establishing priorities for these remedial actions.

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Background

The Metropolitan Toronto area encompassing the Lake Ontario waterfront and the watersheds from Etobicoke Creek to the Rouge River has been designated as one of 17 areas of concern in Ontario by the Great Lakes Water Quality Board of the International Joint Commission (IJC). The IJC has recommended the development of a Remedial Action Plan (RAP) for the restoration of the waterfront and watersheds to their desired uses. The "Metro Toronto and Region RAP" is to include a description of the causes of pollution and proposed measures for remediation. Development of the Metro Toronto and Region RAP is being led by both the federal and provincial governments. In developing the RAP, the RAP Team has recognized a deficiency in contaminant and flow data for various discharges to the waterfront.

The Metropolitan Toronto Waterfront, extending from Etobicoke Creek to the west and east to the Rouge River, receives flow from the following sources:

- effluent from 3 water pollution control plants (WPCPs);
- backwash water from 3 water filtration plants (WFPs);
- over 100 storm sewers (31 of which receive combined sewer overflows); and
- six watersheds (Humber, Don and Rouge Rivers, and Etobicoke, Mimico and Highland Creeks).

In support of the development of the RAP, several studies evaluating contaminant discharges to the waterfront have been initiated by the Ontario Ministry of Environment and Energy. A brief overview of each study is presented below.

1. **Dry Weather Discharges to the Metropolitan Toronto Waterfront** -evaluated contaminant concentrations and contaminant mass loadings associated with dry weather discharges from sewer outfalls within the Cities of Etobicoke, Toronto, and Scarborough, backwash water discharges from the WFPs, and effluent discharges from WPCPs (Snodgrass and D'Andrea, 1993).

2. **Assessment of Pollutant Loadings from Tributaries Discharging to the Metropolitan Toronto Waterfront** - an enhanced tributary monitoring program was established in this study to evaluate pollutant loadings from tributaries discharging to the waterfront. A Metropolitan Toronto and Region RAP report is being prepared.

3. **Metropolitan Toronto Waterfront Wet Weather Outfall Study Phase I** - evaluated contaminant concentrations and contaminant mass loadings associated with wet weather discharges from sewer outfalls within the Cities of Etobicoke and Scarborough, bypasses of primary effluent from the Metro Main WPCP, and discharges from the Berry Street combined sewer overflow (CSO) upstream of the Humber WPCP (Paul Theil Associates Limited *et al.*, 1992).

4. **Metropolitan Toronto Waterfront Wet Weather Outfall Study Phase II** - contaminant concentrations and contaminant mass loadings associated with wet weather discharges to the waterfront from sewer outfalls within the City of Toronto and secondary treatment bypasses at the Main WPCP were evaluated in the present study.

Collectively, the estimates of contaminant concentrations and contaminant mass loadings from the above-noted studies will be used by the RAP Team and other agencies to assess the relative importance of waterfront discharges, establish priorities for remedial actions and assist the continued development of the Metro Toronto and Region Remedial Action Plan.

1.2 Significance of Wet Weather Discharges

Historically, discharges from storm sewers were considered relatively "clean" and were not thought to be significant sources of contaminants relative to discharges from sewage treatment plants or combined sewer overflows. However, recent studies have shown that discharges from storm sewers can be a major source of pollutant loadings due to washoff of accumulated contaminants (U.S. EPA, 1983; Marsalek *et al.*, 1987). Sources of these contaminants include nutrients and pesticides spread on lawns, heavy metals and exhaust emissions from automobiles, petroleum and chemical spills in industrial areas, bacterial contamination from fecal droppings of domestic pets and birds, direct or indirect connections with the sanitary sewer system, and contaminants associated with atmospheric deposition.

In general, the majority of wet weather runoff volume in urban areas is generated from impervious surfaces, such as roads, parking lots, and roofs. These surfaces have limited natural treatment capability and are therefore likely to convey a majority of any accumulated contaminant loadings. Pervious, or grassed areas, also contribute a significant volume of runoff during severe storm events or during periods when the ground is either frozen or seasonally wet.

Combined sewer overflows on the other hand, in addition to conveying the contaminants described above, will also convey high levels of nutrients, ammonia, and bacteria associated with sanitary sewage from residential and industrial areas. Furthermore, contaminant levels of various non-conventional parameters (i.e., industrial organics) may be significant depending upon the type and intensity of industry which is serviced.

Under wet weather conditions, water pollution control plants may also discharge significant loadings of various parameters (eg. ammonia, phosphorus, bacteria, and some heavy metals) through secondary treatment bypasses at the plant.

1.2.1 Receiving Water Impacts Attributed to Waterfront Discharges

The Remedial Action Plan Team (Environment Canada *et al.*, 1990) has summarized the major environmental impairments of the nearshore areas along the waterfront.

Those impairments attributable to the sources considered in this study are outlined below.

1. Beach postings as a result of elevated bacterial densities in excess of the Provincial Water Quality Guideline.

2. High nutrient levels, particularly phosphorus, which results in nuisance algal growth in some sections of the waterfront.

3. Degraded water clarity, which is influenced by nutrient controlled algal growth and discharges of suspended solids.

4. Elevated levels of nutrients, organics and metals in freshwater sediments.

5. A stressed aquatic community, including benthic (sediment dwelling) organisms, primarily in areas close to direct discharges such as water pollution control plants and sewer outfalls.

1.3 Study Objectives and Scope of Work

The primary objectives of this study were to characterize contaminant concentrations and estimate contaminant mass loadings associated with wet weather discharges from sewer outfalls and water pollution control plants along the City of Toronto waterfront. The following scope of work was undertaken to satisfy study objectives:

- completion of a field program to provide flow monitoring and water quality data from representative sites within the City of Toronto;

- compilation of a water quality database to determine contaminant concentration characteristics associated with wet weather discharges;

- application of an urban runoff prediction model for the estimation of runoff volumes from sewer outfalls;

- estimation of seasonal bypass volumes from the Main Water Pollution Control Plant; and

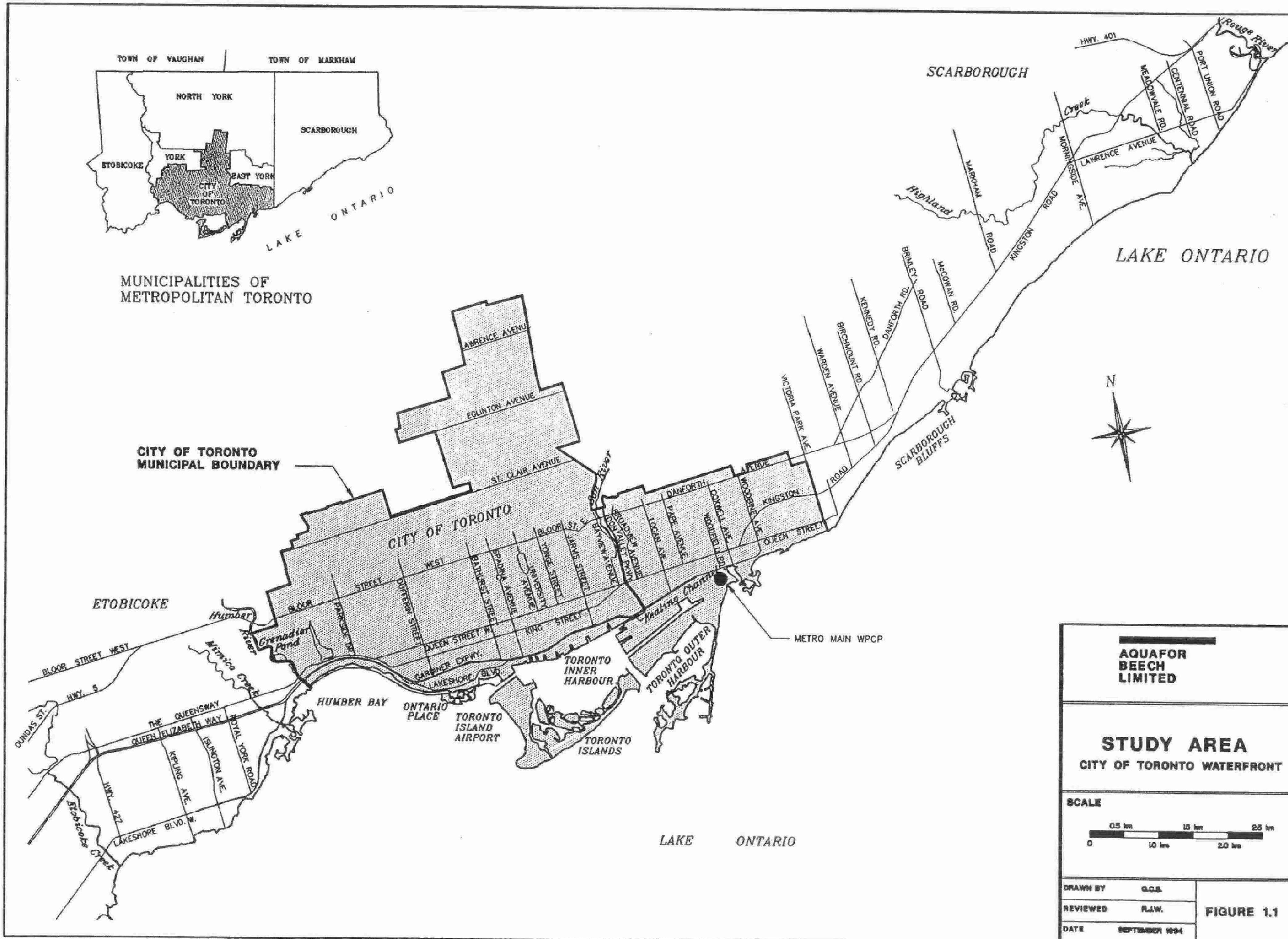
- estimation of seasonal contaminant mass loadings from sewer outfalls discharging along the City of Toronto waterfront and the Main WPCP Bypass.

1.4 Description of the Study Area

The study area, as shown in Figure 1.1, consists of the areas within the City of Toronto draining directly to the Lake Ontario waterfront. The City of Toronto waterfront extends approximately 20 kilometres from the mouth of the Humber River to Victoria Park Avenue at the Toronto/Scarborough municipal boundary.

Overviewed in this section are several relevant characteristics of the City of Toronto sewerage system. A detailed description of the sewerage system has been provided by Gore & Storrie Limited *et al.* (1991).

The City of Toronto sewerage system was originally built as a combined sewer system with sewers typically running from north to south towards Lake Ontario. The combined sewerage system was designed to convey both sanitary sewage and storm runoff in the same pipe to the nearest water pollution control plant for treatment. Occassionally, the combined sewers overflow and/or water pollution control plants bypass primary effluent to the receiving waters. This occurs if the sewerage system and/or water pollution control plants cannot accommodate the increased flow during periods of rainfall and/or snowmelt. At the



STUDY AREA
CITY OF TORONTO WATERFRONT
FIGURE 1.1

Metro Main WPCP, for example, bypass flow is discharged through the plant's outfall diffuser located about 1000 metres offshore in the Ashbridges Bay area.

Since 1965, the City of Toronto has been undertaking an extensive sewer separation program. As part of this program, road storm sewers have been installed to collect runoff from street drainage and paved surfaces around buildings. This has resulted in numerous areas within the City of Toronto which are partially separated, whereby, part of the separated storm flow is conveyed by the road storm sewers, and the balance of the storm flow (i.e., roof drainage) is conveyed with sanitary sewage by combined sewers. In addition, under the City of Toronto sewer separation program, both separate storm sewer and sanitary sewer systems are required for all new development. Consequently, the degree of sewer separation varies throughout the City. This has resulted in a very complex sewer network with the construction of numerous interconnection and diversion chambers to alleviate basement flooding and reduce combined sewer overflows. There are approximately 600 internal overflows from the combined sewer system, of which approximately 180 overflow to waterfront outfalls (A. Marich, 1992).

Within the City of Toronto, the sewered area consists of approximately 8,300 hectares. Of this area, 61 percent is serviced by sewers discharging directly to Lake Ontario. Similarily, sewers discharging to the Don River and Humber River service approximately 36 percent and 3 percent of this area, respectively (Gore & Storrie Limited *et al.*, 1991).

Two distinct types of sewer outfalls which discharge to the waterfront have been identified as follows:

- outfalls which receive storm water from areas serviced by separate storm sewers (Storm); and

- outfalls which receive both storm water from separated sewer areas and combined sewer overflows (CSO) from areas serviced by combined sewers.

The two respective outfall types have been designated as either "Storm" or "CSO". Illustrated in Figure 1.2 are both storm sewer and combined sewer outfalls which discharge to the City of Toronto waterfront. In total, there are approximately 53 sewer outfalls which discharge to Lake Ontario.

As shown in Figure 1.2, the sewer outfalls along the waterfront can be divided into four distinct regions which are labelled with a letter prefix as follows:

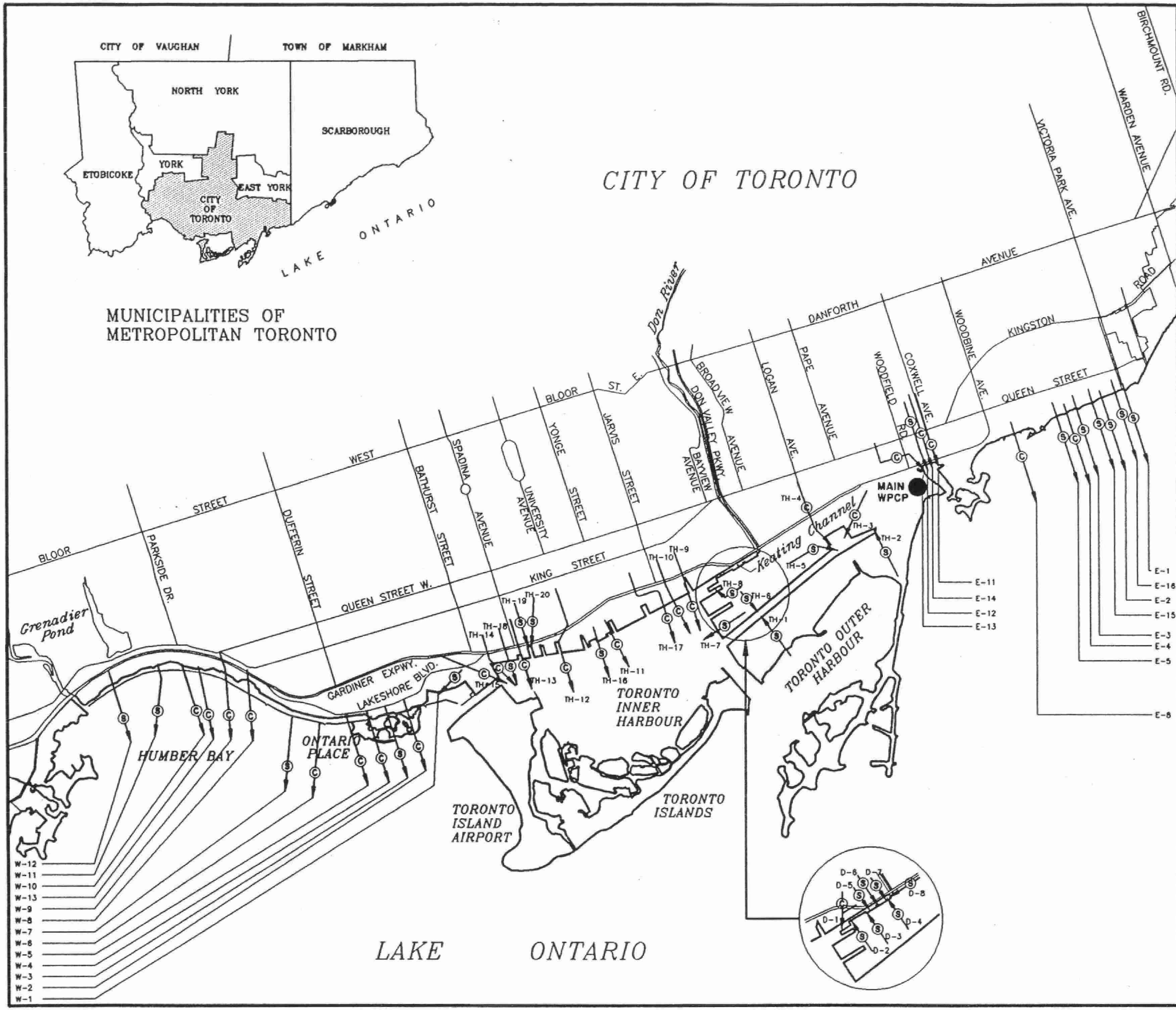
- Western Beaches (W series);
- Toronto Inner Harbour (TH series);
- Ashbridges Bay (E series); and
- Eastern Beaches (E series).

In addition, 8 of the 53 sewer outfalls discharge to the Keating Channel (D series). These D series outfalls (D1, D2, D3, D4, D5, D6, D7 and D8) have been considered as discharging to the Toronto Inner Harbour.

Overall, the 29 outfalls discharging storm water from separate storm sewer systems, the 24 outfalls which receive combined sewer overflows, and the bypass discharge of primary effluent from the Metro Main WPCP were considered in this study. Characteristics of these outfalls are summarized in Table 1.1.

1.5 Significance of this Study

It is anticipated that the results of this study will be used to assist in the ongoing development, prioritization, and design of remedial options, and will form a database whereby the effectiveness of remedial measures can be evaluated once implemented. As outlined in this section, the results of this study provide a significant amplification of previous studies which have investigated wet weather discharges to the Metropolitan Toronto waterfront.



LEGEND

Ⓢ STORM SEWER

Ⓒ COMBINED SEWER

● METRO MAIN WPCP

E-8 Overflow from Eastern Beaches Detention Tank

NOTE

Refer to City of Toronto Combined Sewer and Storm Sewer Drainage Network drawings for schematic of sewerage system.

AQUAFOR BEECH LIMITED

TORONTO WATERFRONT STORM SEWER OUTFALLS AND COMBINED SEWER OVERFLOWS

SCALE

0 — 0.5 km — 1.0 km — 1.5 km — 2.0 km — 2.5 km

DRAWN BY	G.C.S.	FIGURE 1.2
REVIEWED	R.J.W.	
DATE	SEPTEMBER 1994	

For example, several studies which have provided information on wet weather discharges to the Metropolitan Toronto waterfront include:

- studies completed as part of the Toronto Area Watershed Management Study (TAWMS);
- City of Scarborough Pollution Control Strategy (Proctor and Redfern Limited, 1987); and
- City of Toronto Sewer System Master Plan - Phase I (Gore & Storrie Limited *et al.*, 1991).

The contaminant concentrations and/or mass loadings presented in these studies were generally limited to conventional water quality parameters, such as biological oxygen demand, suspended solids, nutrients, bacteria, and a few heavy metals. Organic parameters were generally not analyzed in the collected samples and/or method detection limits were relatively high. Therefore, the issue of presence/absence was not clear for organic parameters. A strong emphasis was placed on the analysis of trace organic compounds, in addition to conventional water quality parameters and heavy metals in the present study and the previous Phase I study (Paul Theil Associates Limited, et al., 1992). This has involved special sample collection and analytical procedures, and the application of non-traditional statistical techniques in the analysis of water quality data sets containing information at or below the analytical detection limit. The collection of large volume samples and special analytical procedures provided detection limits about one order of magnitude lower than traditional techniques. Contaminant concentrations and mass loadings have also been provided for bypasses of primary effluent at the Metro Main WPCP.

It is intended that the information presented in this study can also be used to augment and expand existing water quality databases which are commonly used to characterize

contaminant concentrations associated with urban runoff, such as the database developed under the Nationwide Urban Runoff Program (U.S. EPA, 1983).

TABLE 1.1: SUMMARY OF SEWER OUTFALL CHARACTERISTICS [1]

OUTFALL	LOCATION	TYPE[2]	SIZE (metres)	LAND USE
WESTERN BEACHES				
W12	Ellis Ave.	Storm	1.35 dia.	Mostly Residential
W11	Howard Rd.	Storm	0.75 dia.	
W10	Parkside Dr.	CSO (33%)	3.75 x 1.80	Residential, some Industrial & Commercial
W13	Glendale Ave. (Sunnyside)	CSO (65%)	2.85 x 3.60	Mostly Residential
W9	Roncesvalles Ave.	CSO (80%)	2.10 x 2.10	Residential, some Commercial
W8	Wilson Ave.	CSO (99%)	1.05 dia.	Residential, some Commercial
W7	Jameson Ave.	Storm	1.20 dia.	
W6	Cowan Ave.	CSO (74%)	2.70 dia.	Residential, some Industrial
W5	Dufferin St.	CSO (80%)	2.10 x 1.95	Residential, some Commercial
W4	Aberdeen Rd. (CNE)	CSO	0.90 dia.	Canadian National Exhibition Grounds
W3	Remembrance Dr. (CNE)	Storm	0.90 dia.	Canadian National Exhibition Grounds
W2	Strachan Ave.	CSO (100%)	3.60 x 3.00	Residential, some Industrial & Commercial
W1	Queens Quay West	Storm	0.60 dia.	
TORONTO INNER HARBOUR				
TH15	Bathurst St. (Garrison Creek)	CSO (69%)	Twin 1.80 x 2.70	Residential, some Commercial
TH14	Portland St.	CSO (29%)	3.75 dia.	Residential
TH18	Queens Quay West	Storm	0.90 dia.	
TH13	Spadina Ave.	CSO (50%)	1.80 x 2.40	Residential, some Commercial
TH19	Queens Quay West	Storm	0.60 dia.	
TH20	Rees St.	Storm	2.70 dia.	Commercial
TH12	Simcoe St.	CSO (67%)	2.45 x 1.63	Residential, some Commercial
TH16	Bay St.	Storm	0.90 dia.	
TH11	Yonge St.	CSO (67%)	2.4 x 1.95	Residential, some Commercial
TH17	Jarvis St.	CSO (98%)	3.0 dia.	Residential, some Commercial
TH10	Sherbourne St.	CSO (34%)	3.05 dia.	Residential, some Commercial
TH9	Parliament St.	CSO (39%)	2.1 x 1.5	Residential, some Commercial
TH8	West end of Commissioners St.	Storm	0.9 x 0.9	Industrial
TH7	West end of Poulson St.	Storm	0.60 dia.	Industrial
TH6	Cherry St. north of Ship Channel	Storm	0.60 dia.	Industrial
TH5	Basin St. to Turning Basin	Storm	0.675 dia.	Industrial
TH4	Carlaw Ave.	CSO (31%)	Twin 2.55 x 1.80	Residential, some Commercial
TH3	Leslie St.	CSO (27%)	Twin 2.60 x 1.50	Residential, some Commercial
TH2	East end of Ship Channel	Storm	0.75 dia.	Industrial
TH1	Cherry St. south of Ship Channel	Storm	0.45 dia.	Industrial

TABLE 1.1: SUMMARY OF SEWER OUTFALL CHARACTERISTICS [1] (cont'd)

OUTFALL	LOCATION	TYPE[2]	SIZE (metres)	LAND USE
<u>TORONTO INNER HARBOUR KEATING CHANNEL OUTFALLS</u>				
D1	Cherry St.	CSO (59%)	1.35 x 1.35	Residential, some Commercial
D2	West of Munition St.	Storm	0.60 dia.	Industrial
D3	Munition St. to Keating Channel	Storm	0.45 dia.	Industrial
D4	Villiers St. to Keating Channel	Storm	1.05 dia.	Industrial
D5	Lakeshore Rd. east of Cherry St.(I)	Storm	0.53 dia.	Industrial
D6	Lakeshore Rd. east of Cherry St.(II)	Storm	0.60 dia.	Industrial
D7	Lakeshore Rd. west of Don River	Storm	0.53 dia.	Industrial
D8	Lakeshore Rd. and Don Roadway	Storm	0.90 dia.	Industrial
<u>ASHBRIDGES BAY REGION</u>				
Main WPCP Bypass	Submerged outfall 1,000 metres off-shore	Bypass		
E13	Near Woodfield Rd.	CSO (56%)	2.10 x 2.63	Mostly Residential
E12	East of Woodfield Rd.	Storm	Twin 1.80 x 2.10	Mostly Residential
E14	Coxwell Ave.	CSO (100%)	2.10 dia.	Mostly Residential
E11	East of Coxwell Ave./Eastern Ave.	CSO (59%)	Twin 2.33 x 3.30	Mostly Residential
<u>EASTERN BEACHES[3]</u>				
E8	Kenilworth Ave. (Phase I Detention Tank Overflow)	CSO (50%)	2.03 x 1.20	Mostly Residential
E5	Glen Manor Dr.	Storm	1.60 dia.	Mostly Residential
E4	Maclean Ave.	CSO (96%)	Twin 1.95 x 0.95	Mostly Residential
E3	Balsam Ave.	Storm	1.90 x 1.20	Mostly Residential
E15	Willow Ave.	Storm	0.75 dia.	Mostly Residential
E2	Silver Birch	Storm	0.60 dia.	Mostly Residential
E16	Neville Park Blvd.	Storm	0.53 dia.	Mostly Residential
E1	Nursewood Ave.	Storm	0.90 dia.	Mostly Residential

Note: See Figure 1.2 for sewer outfall locations.
1. after Gore & Storrie et al. (1991).
2. "Storm" designates an outfall which receives storm water from areas serviced by separate storm sewers. "CSO" designates an outfall which receives both storm sewer discharges and combined sewer overflows. The percentage in brackets for the CSO outfalls represents the percentage of the sewershed area serviced by combined sewers (see Appendix B).
3. Outfalls E3, E4, and E5 will ultimately (1994) discharge to the Phase II Eastern Beaches Detention Tank.

2.0 STUDY APPROACH

2.1 Field Program for Runoff Quantity and Quality Measurements

The primary objective of the field program was to collect water quantity and quality data representative of the catchment areas draining to the City of Toronto waterfront. In designing the field program, the following factors were considered:

- runoff volumes and contaminant concentrations from storm sewers and combined sewers are likely to be different;

- runoff volumes and contaminant concentrations may vary based on land use;

- the conveyance of urban runoff and the associated contaminants during a rainfall event is a dynamic process, therefore, significant variations in flow volume and contaminant concentrations will occur during the course of an event;

- runoff volumes and contaminant concentrations will vary between events;

- runoff volumes and associated contaminant concentrations may vary seasonally; and

- for a given outfall, there are many contaminants which are to be monitored.

The collection and analysis of flow monitoring data and water quality samples from each of the 53 sewer outfalls for any reasonable time period would be extremely labour intensive and cost prohibitive. For this reason, a field program was designed to monitor flows and collect samples from representative outfalls which could then be used to extrapolate flow volumes and contaminant loadings for the entire study area.

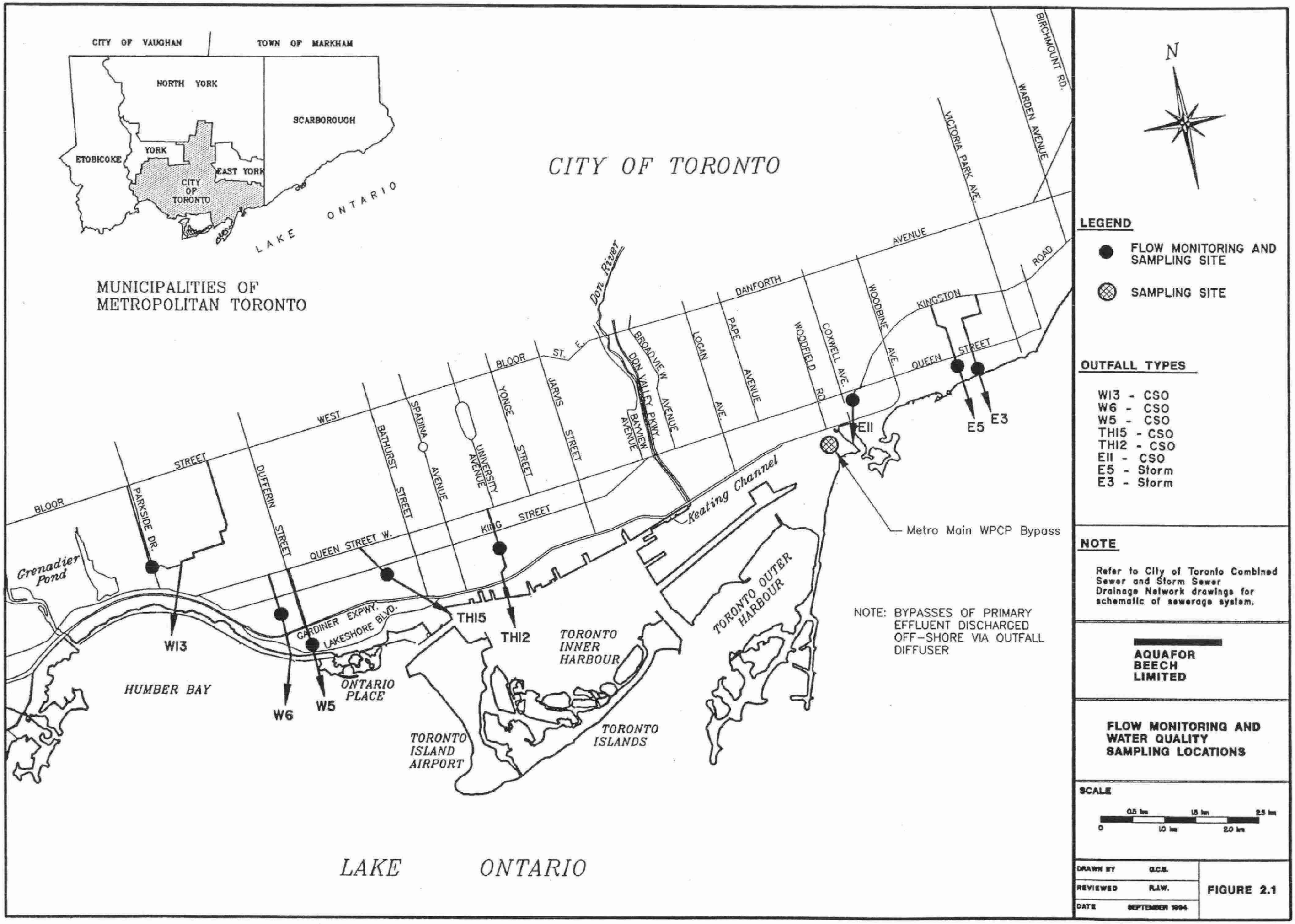
The location of flow monitoring and water quality sampling sites is provided in Figure 2.1. A total of 8 sites were selected for flow monitoring and 9 sites for the collection of water quality samples. Characteristics of these sites are summarized in Table 2.1.

The sites were selected based on various factors, including:

- drainage area;
- land use;
- type of sewershed;
- geographic region; and
- complex nature of the sewer system.

Initially, the intent was to undertake the field program at storm sewer and combined sewer outfalls with distinct singular land uses. However, based on a review of the complex and interconnected nature of the City of Toronto sewer system, the monitoring sites were chosen in consultation with City of Toronto staff, to represent typical characteristics (i.e., land use, sewer type) of sewers discharging to the Western Beaches, Inner Harbour, Ashbridges Bay, and Eastern Beaches. These sites included 2 outfalls which receive storm water from separate storm sewers and 6 outfalls which receive both storm water and combined sewer overflows. The portion of the upstream sewershed serviced by combined sewers for the six CSO designated outfalls ranged from 59 percent (E11) to 80 percent (W5). In addition to the eight sewer outfalls, the bypass from the Metro Main WPCP was also monitored.

The field program was initiated 14 September 1990 and completed 15 December 1990. As an extension to the Phase II field program, flow monitoring and water quality sampling was continued at sites E5 and W5 through to September 1991 to characterize winter/spring flows and contaminant concentrations. The analysis of this data is being conducted through a parallel Phase III study (Aquafor Beech Limited, 1994).


CITY OF VAUGHAN
TOWN OF MARKHAM
NORTH YORK
SCARBOROUGH
ETOBICOKE
YORK
EAST YORK
CITY OF TORONTO
LAKE ONTARIO
MUNICIPALITIES OF METROPOLITAN TORONTO
CITY OF TORONTO
N
LEGEND
FLOW MONITORING AND SAMPLING SITE
SAMPLING SITE
OUTFALL TYPES
WI3 - CSO
W6 - CSO
W5 - CSO
THI5 - CSO
THI2 - CSO
EII - CSO
E5 - Storm
E3 - Storm
NOTE
Refer to City of Toronto Combined Sewer and Storm Sewer Drainage Network drawings for schematic of sewerage system.
AQUAFOR BEECH LIMITED
FLOW MONITORING AND WATER QUALITY SAMPLING LOCATIONS
SCALE
0.5 km
1.5 km
2.5 km
0
1.0 km
2.0 km
DRAWN BY G.C.S.
REVIEWED R.J.W.
DATE SEPTEMBER 1994
FIGURE 2.1
BIRCHMOUNT RD.
WARDEN AVENUE
VICTORIA PARK AVE.
DANFORTH AVENUE
ROAD
KINGSTON
WOODBINE AVE.
COXWELL AVE.
WOODFIELD RD.
PAPE AVENUE
LOGAN AVE.
BROADVIEW AVENUE
DON VALLEY PKWY.
BAYVIEW AVENUE
Don River
BLOOR ST. E.
JARVIS STREET
YONGE STREET
UNIVERSITY AVENUE
SPADINA AVENUE
BATHURST STREET
DUFFERIN STREET
PARKSIDE DR.
BLOOR STREET WEST
QUEEN STREET
QUEEN STREET W.
KING STREET
Keating Channel
GARDINER EXPWY.
LAKESHORE BLVD.
Grenadier Pond
HUMBER BAY
WI3
W6
W5
THI5
THI2
EII
E5
E3
ONTARIO PLACE
TORONTO ISLAND AIRPORT
TORONTO INNER HARBOUR
TORONTO ISLANDS
TORONTO OUTER HARBOUR
Metro Main WPCP Bypass
NOTE: BYPASSES OF PRIMARY EFFLUENT DISCHARGED OFF-SHORE VIA OUTFALL DIFFUSER
LAKE ONTARIO

2.1.1 Flow Monitoring and Water Quality Sampling Program

The collection of representative urban runoff flow and water quality data during wet weather conditions requires the use of special procedures and equipment. Several factors which influenced the sampling protocol and equipment selection in this study were as follows:

- requirement to collect samples which account for the variability in flow volume and contaminant concentration through a given runoff event;
- requirement to collect an adequate sample volume in order that the analysis of up to 90 water quality parameters, including trace organics, could be undertaken; and
- requirement to monitor flows and collect samples over a range of events.

Many of the parameters analyzed included trace organic priority pollutants. These parameters, such as dieldrin and mirex, are persistent and toxic in the natural environment and are generally found in very low concentrations. Analytical procedures for these parameters require sample volumes considerably larger than those used for conventional water quality parameters (i.e., suspended solids, total phosphorus, and bacteria). In this study, the sample volume for the analysis of trace organics was increased from 1 litre to 16 litres in order to improve the detection limit by a factor of ten over traditional analyses. An additional sample volume of 4 litres was used for the analysis of the remaining parameters. The collection of a 20 litre sample representative of mean conditions over the entire event required customized retrofitting of sampling equipment.

Twenty (20) litre flow proportional composite water quality samples were collected to account for the variability of runoff concentrations caused by non-uniform washoff rates during a rainfall event. Variation in the washoff rate is a function of several factors but is

dominated by factors such as inter-event period, varying rainfall intensity, and the nature of the runoff surface.

Montedoro Whitney Q-Logger flow monitoring equipment was used to continuously record flow depth and velocity. The depth and velocity sensors are both contained within a single probe which is installed at the invert of the sewer pipe. Velocity is measured by a Doppler ultrasonic sensor. The Q-Logger is programmed and readings are retrieved using a portable computer.

The flow monitoring equipment was set to measure flow at 5 minute intervals. This time step was considered adequate for determining event runoff volumes as it was short enough to capture peak flows and large enough so as not to generate excessive amounts of data. Flow measurements were made using the velocity area method, whereby, flow is calculated based on independent depth and velocity measurements, and characteristics on the installation site (i.e., pipe diameter). Flow data was retrieved and processed using Montedoro Whitney Q-Base and Lotus 1-2-3 software.

The flow monitor can be interfaced with an automatic wastewater sampler for the collection of flow dependent sample aliquots. The sampler triggering device on the Q-Logger has three settings. The first setting is a threshold depth which initiates the sampling cycle. The second setting is a totalizer volume which is preset. Once flow has accumulated to the preset volume, a sample is collected. As the flow rate increases, the preset volume is obtained quicker and the sampler will sample more frequently. This results in the collection of a larger sample volume at the higher rates of flow. The last setting establishes the threshold flow above the threshold depth. The samplers were set to use a higher flow setting to minimize possible sampling of dry weather flows.

Composite samples were obtained by the collection of several flow weighted 1 litre sample aliquots through a given event. A representative sample collection regime is illustrated in Figure 2.2. The "S" represents sampler operation.

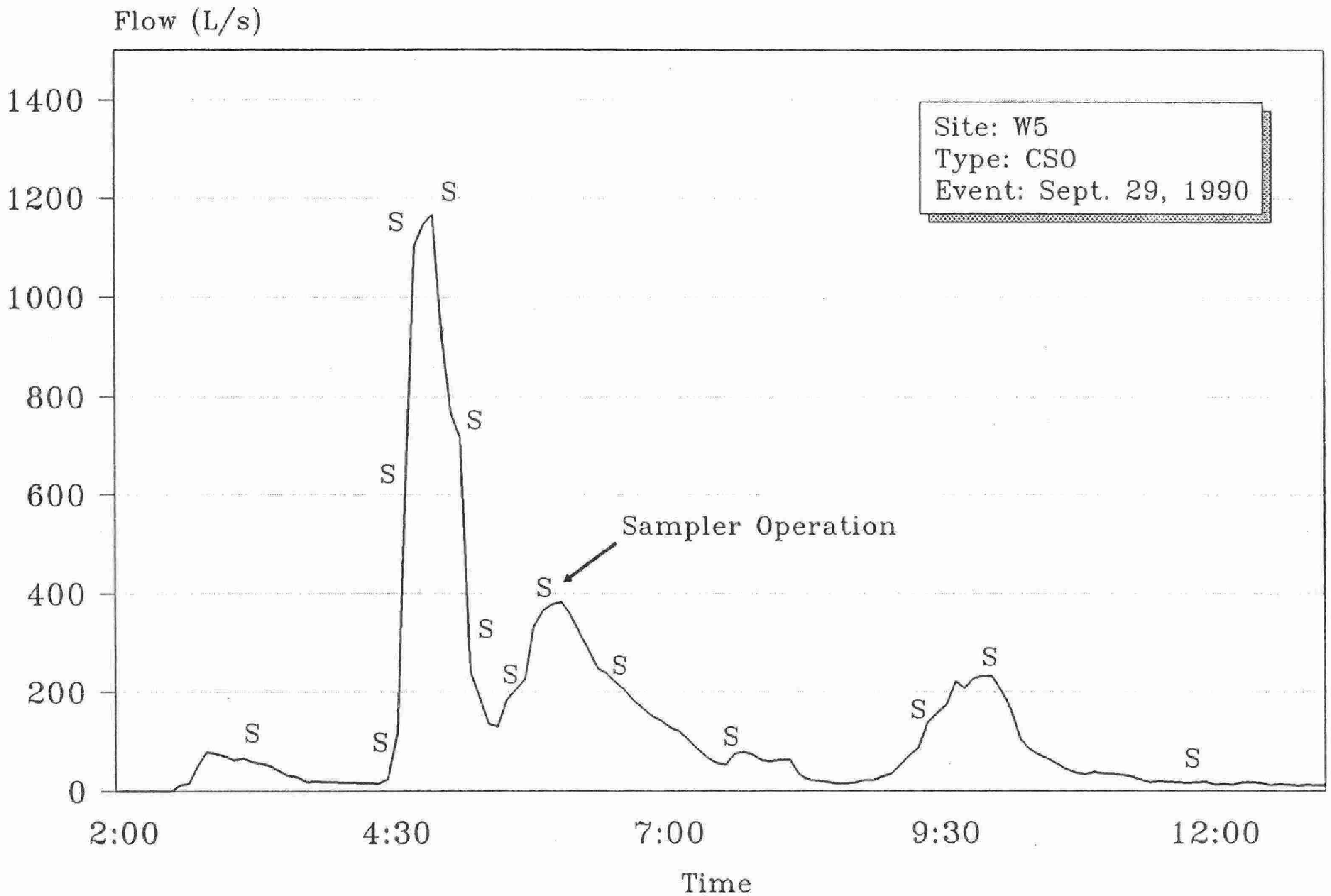


FIGURE 2.2: STORM EVENT PROPORTIONAL SAMPLING REGIME ("S" represents the collection of a sample aliquot)

It was not possible to collect 20 litre samples for each event due to the variability of rainfall events both in duration and total depth. For small events, less than 20 litres would typically be collected. Whereas, the 20 litre sample would generally be collected during the initial stages of larger events. Throughout the course of the study, it was necessary to adjust the preset sampling settings to accommodate the type of events anticipated.

ISCO Model 2700 samplers were used to collect the water quality samples. These samplers use peristaltic pumps. The only material in contact with this pumping system is surgical grade silicone tubing. Teflon lined polyethylene tubing was used for the intake line. This system minimizes cross-contamination of samples. One of the programming features of this sampler is the capability of the device to accept triggering for sample collection from an external signal such as a flow meter. The standard sampler capacity for a composite sample in a glass container is 9.5 litres (ISCO, 1986). Retrofitting of the samplers for the collection of 20 litres required disconnection of the standard pump effluent hose from the sampler distribution arm and extending the hose with teflon lined tubing for discharge directly into a larger 23 litre glass jug external to the sampler.

The samplers were turned on during installation and remained in standby mode until they were actuated by the flow meters. The actuation by the flow meter was based on a preset threshold water level. The threshold level was initially set based on information available from the recent dry weather study of waterfront outfalls (Beak Consultants Limited, 1991) and the prevailing conditions at time of installation. Throughout the course of the study, adjustment of the threshold level was necessary in order to account for different base flow and associated water levels within the sewers, and in some locations, the backwater effects from Lake Ontario.

The samples were retrieved and prepared for submission to the Ontario Ministry of the Environment and Energy Laboratory Services Branch, generally, within 24 hours of collection. Sample preparation required the volume collected to be split into the appropriate bottles for analysis. At all times, equipment and sample bottles were cleaned and preserved

as required, following Ontario Ministry of the Environment and Energy sample collection, preservation, and submission protocol. Requests for analysis were prioritized based on the volume collected. For example, if 16 litres was collected, the analysis of trace organic parameters took priority. Any additional volume was used for the other parameters. Sample volumes less than 16 litres did not allow for the analysis of trace organics, and therefore, only the remaining parameters were analyzed.

2.2 Sample Handling and Analytical Methods

To ensure a high level of quality and consistency during the field sampling phase, specific procedures were established prior to initiating the sampling program. A pre-designed field form was prepared in order to ensure that all pertinent field data was collected and that the required equipment checks and maintenance procedures were performed. All sampling team members completed a "hands-on" dry run of sample handling and equipment reset procedures. Included in the training was a review of safety procedures, handling of preservative chemicals, sewer confined space entry requirements, and use of safety equipment.

Sample bottles, pre-cleaned by Ontario Ministry of the Environment and Energy staff, were used for the submission of all samples, except those to be analyzed for trace organic parameters (16 litre samples). The 16 litre samples were submitted in amber 4 litre bottles which were purchased and cleaned using the required washing protocol.

2.2.1 Parameters Analyzed

In total, 85 parameters were analyzed in this study. These parameters are summarized in Table 2.2 and have been broken down into the following five general groups:

- General Chemistry;
- Bacteriology;
- Heavy Metals;
- Organochlorine Pesticides, Chlorobenzenes, and PCBs; and

- Polynuclear Aromatic Hydrocarbons (PAHs).

The Ontario Ministry of the Environment and Energy Laboratory Services Branch performed the chemical analysis for all conventional parameters and heavy metals. Analytical methodologies described by the Ontario Ministry of the Environment (1988) were used in these analyses. The solvent extraction of the large volume samples for trace organic analyses and chemical analyses of organochlorine pesticides, chlorobenzenes, and PCBs was performed by Mann Testing Laboratories. The Ontario Ministry of the Environment and Energy Laboratory Services Branch performed the chemical analyses of polynuclear aromatic hydrocarbons for these samples.

The water quality data presented in this report is based on the analysis of flow weighted composite samples collected during runoff events. This data is considered to be representative of the mean concentration over the duration of the event and will henceforth be referred to as Event Mean Concentrations (EMCs).

TABLE 2.1: FLOW MONITORING AND WATER QUALITY SAMPLING SITE CHARACTERISTICS

Site	MOE Station	Field Program[1]		Outfall Type[4]	Location	Comments
		A	B			
W13	81	√	√	CSO (65%)	Glendale Ave. south of Parkdale Ave.	Representative of outfalls west of Jameson Ave.
W6	82	√	√	CSO (74%)	Cowan Ave. north of Springhurst Ave.	Representative of outfalls eastward to Inner Harbour.
W5[3]	83	√	√	CSO (80%)	CNE grounds east of Dufferin St.	Receives some industrial area storm runoff. "Stand-alone" outfall with unique features.
TH15	84	√	√	CSO (69%)	Wellington St. west of Walnut Ave.	Receives drainage from a large area north of Bloor St.
TH12	119	√	√	CSO (67%)	Simcoe St. south of Front St.	Representative of Inner Harbour outfalls. Drains part of downtown core area.
E11[2]	89	√	√	CSO (59%)	Greenwood Race Track and Eastern Ave.	Representative of Ashbridges Bay area outfalls with CSO. Land use primarily residential.
E5[3]	90	√	√	Storm	Glen Manor Drive south of Queen St.	Representative of eastern beaches area storm sewer outfalls. Constant baseflow at monitoring site.
E3	118	√	√	Storm	Balsam Ave. north of Hubbard Boulevard	Representative of eastern beaches area storm sewer outfalls. Land use primarily residential.
Bypass	1		√	WPCP Bypass	Metro Main WPCP	Bypass of primary effluent.

1. A - flow monitoring, B - water quality sampling.
2. Flow monitoring and water quality sampling was undertaken at this site as part of the Metropolitan Toronto Waterfront Wet Weather Outfall Study - Phase I.
3. Flow monitoring and water quality sampling continued at these sites through to September 1991.
4. "Storm" designates an outfall which receives storm water from areas serviced by separate storm sewers. "CSO" designates an outfall which receives both storm sewer discharges and combined sewer overflows. The percentage in brackets for the CSO outfalls represents the percentage of the sewershed area serviced by combined sewers (see Appendix B).

TABLE 2.2: SUMMARY OF PARAMETERS ANALYZED

GENERAL CHEMISTRY	BACTERIOLOGY	HEAVY METALS[1]	ORGANOCHLORINE PESTICIDES/CHLOROBENZENES	POLYNUCLEAR AROMATIC HYDROCARBONS
Alkalinity	Escherichia Coliform MF	Aluminum	Aldrin	Acenaphthene
Cyanide - avl. unfilt. react.	Fecal Coliform MF	Arsenic	Alpha-bhc	Acenaphthylene
Cyanide - free unfilt. react.	Fecal Streptococcus MF	Barium	Beta-bhc	Anthracene
Chemical Oxygen Demand	Pseudomonas Aeruginosa MF	Berylium	Gamma-bhc (Lindane)	Benzo (A) Anthracene
Ammonium - tot. filt. react.		Cadmium	Chlordane - alpha	Benzo (A) Pyrene
Nitrates - tot. filt. react.		Chromium	Chlordane - gamma	Benzo (B) Fluoranthene
Nitrite - filt. react.		Copper	Dieldrin	Chrysene
Total Kjeldahl Nitrogen		Iron	DMDT - Methoxychlor	DiBenzo (AH) Anthracene
Phenolics - unfilt. react.		Mercury	Endrin	Fluoranthene
Total Phosphorus		Manganese	Endosulfan - Sulphate	Fluorene
Total Suspended Solids		Nickel	Endosulfan - I	Benzo (G,H,I) Perylene
Residue - total		Lead	Endosulfan - II	Indeno (1,2,3-CD) Pyrene
Solvent Extractables		Selenium	Heptachlorepoxide	Naphthalene
		Silver	Heptachlor	Perylene
		Zinc	Mirex	Phenanthrene
			Oxychlordane	Pyrene
			OP-DDT	1-Methylnaphthalene
			PCB total	2-Methylnaphthalene
			PP-DDD	
			PP-DDE	
			PP-DDT	
			Hexachlorobutadiene	
			Hexachlorobenzene	
			Hexachloroethane	
			Octachlorostyrene	
			Pentachlorobenzene	
			Trichlorotoluene 2-3-6	
			Trichlorotoluene 2-4-5	
			Trichlorotoluene 2-6-A	
			Trichlorobenzene 1-2-3	
			Tetrachlorobenzene 1-2-3-4	
			Tetrachlorobenzene 1-2-3-5	
			Trichlorobenzene 1-2-4	
			Tetrachlorobenzene 1-2-4-5	
			Trichlorobenzene 1-3-5	

1. All metal concentrations are unfiltered totals.

3.0 FLOW CHARACTERISTICS

A summary is provided in this chapter of seasonal runoff volumes discharged to the City of Toronto waterfront under wet weather conditions by sewer outfalls and the Metro Main Water Pollution Control Plant (WPCP) Bypass. For comparative purposes and consistent with the previous Phase I Metropolitan Toronto Waterfront Wet Weather Outfall Study (Paul Theil Associates Limited *et al.*, 1992), runoff volumes for sewer outfalls are presented based on the 1980 rainfall distribution for the period extending from 01 May through 31 October. The 1980 rainfall distribution is representative of a typical year and the May through October timeframe is coincident with the period of most extensive waterfront recreational usage.

Seasonal runoff volumes for storm sewer and combined sewer outfalls were obtained from the City of Toronto Department of the Works and the Environment. This information is based on the selected "typical year" of 1980 and results from simulations undertaken by City of Toronto staff with the Dorsch Quantity-Quality Simulation (QQS) model. In addition, comparisons have been made between observed and simulated 1990 runoff volumes at applicable flow monitoring and water quality sampling sites. This was undertaken to assess confidence in estimated runoff volumes obtained from the QQS model.

3.1 Precipitation Review

The volume of discharge from wet weather sources (i.e., storm sewers, combined sewer overflows, tributaries, and WPCP bypasses) is significantly influenced by precipitation characteristics, such as rainfall depth, event duration, intensity, and spatial distribution. These precipitation characteristics vary significantly between events, seasons, and years. In the Phase I Metropolitan Toronto Waterfront Wet Weather Outfall Study (Paul Theil Associates Limited *et al.*, 1992), a representative or "typical year" was selected to provide a consistent methodology for comparison of contaminant loadings from municipalities and various sources along the Metropolitan Toronto waterfront. Provided in this section is an

overview of the rationale for the selection of 1980 as the typical year and a comparison of rainfall characteristics over the Phase I (1989) and Phase II (1990) monitoring periods to those of the typical year.

3.1.1 Overview - Typical Year Selection

To facilitate selection of a typical year, a small working group was formed in 1989 made up of the Phase I project team and representatives from municipal, provincial, and federal agencies. The criteria outlined below was developed.

1. The typical year should be based on rainfall data from a climatological station(s) located within the study area and representative of rainfall characteristics along the Metropolitan Toronto waterfront.

2. The typical year should be based on rainfall data from a climatological station(s) that is anticipated to be operational long-term, whereby, the data collected at this station could be used by future studies of a similar nature.

3. The typical year should have seasonal rainfall characteristics consistent with the long-term mean for the selected climatological station(s).

Within the study area, seven applicable Atmospheric Environmental Service (AES) climatological stations were identified. Hourly historical rainfall data from these stations was compiled and reviewed. A summary is provided in Table 3.1 of the seven stations, period of record reviewed, and current operational status. Based on an assessment of available data and discussions with the working group, the following stations were eliminated as they were no longer operational: Etobicoke (6158525); Greenwood (6158575); and Sherbourne (61587PP). In addition, the following two stations were considered to have poor records not suitable for the analysis required: Island Airport (6158665); and Old Weston Road (6158764). The remaining stations were Toronto (Bloor - 6158350) and

Ellesmere (6158520). In the end, the Toronto station was chosen over the Ellesmere station because the Ellesmere station had a shorter period of record, was located further from the waterfront, and was anticipated to be discontinued.

Seasonal rainfall data for each of these two stations was subsequently assessed in further detail with the Rainfall Block of the Storm Water Management Model (U.S. EPA, 1989). This program was applied as it provided the basic analytical capabilities and could incorporate AES formatted data. The following statistics were generated by the Rainfall Block for each of the two stations over the 01 May through 31 October period:

- total seasonal rainfall;
- mean event depth;
- mean event duration;
- mean event intensity; and
- number of events per year.

Each of these parameters, to some degree, affect the magnitude of runoff volume, however, the most significant parameter is the total seasonal rainfall. Upon review of the rainfall statistics, the rainfall distribution from the Toronto station for 1980 was selected as the typical year because it provided the best overall match to historical averages for key parameters.

3.1.2 Summary of Seasonal Rainfall Characteristics

A comparison is provided in this section between seasonal rainfall characteristics (01 May through 31 October) of 1980, 1989, and 1990 to the long-term historical averages. Summarized in Table 3.2 and Figure 3.1 are seasonal rainfall characteristics based on hourly rainfall data and an inter-event period of 6 hours. As shown, it was typically wetter than normal in both 1989 and 1990. Of the four summarized statistics (i.e., seasonal depth, mean event depth, mean event duration, and number of events), the most significant

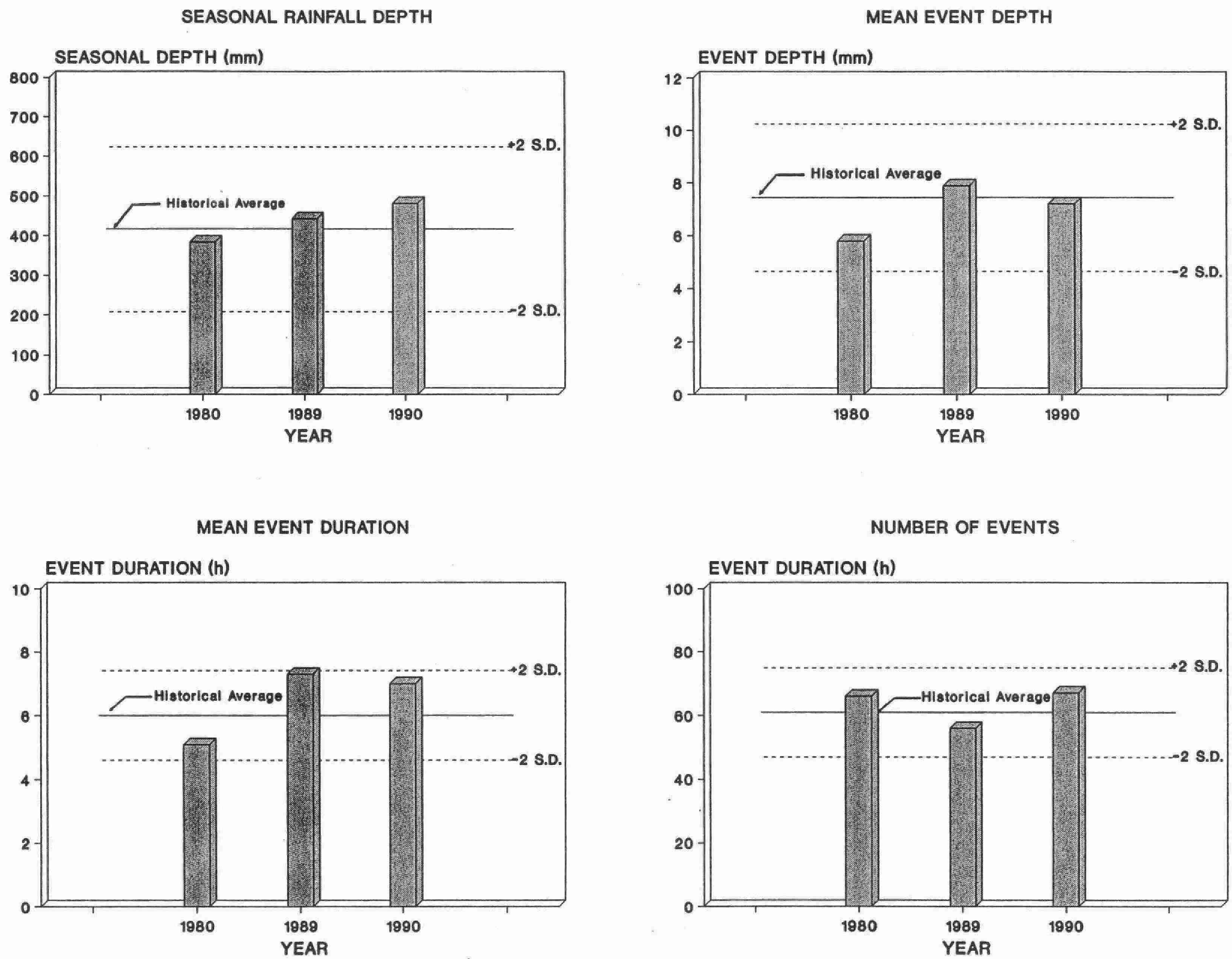


FIGURE 3.1 COMPARISON OF SEASONAL RAINFALL CHARACTERISTICS (01 MAY TO 31 OCTOBER)

parameter that influences the magnitude of runoff volume is seasonal depth. With respect to the typical year (1980), the seasonal depth of 384 mm compares closely to the long-term average of 400 mm. For the other parameters, the 1980 values are generally similar to the historical averages.

A comparison of rainfall characteristics during the 1989 and 1990 monitoring periods to the long-term historical averages is provided in Table 3.3. Although the field programs in 1989 and 1990 both extended into December, about 70 percent to 90 percent of the samples for each site were collected in September and October. As shown in Table 3.3, it was wetter than normal during the 1989 and 1990 September/October monitoring periods. Seasonal rainfall depths for 1989 and 1990 were 34 percent and 17 percent greater than the September/October climate normal, respectively. One implication of wetter than normal conditions over the monitoring periods is that contaminant concentrations, particularly for storm sewer outfalls, may be lower than would be expected.

Of particular note, a storm remnant of Hurricane Hugo passed through the study area on 22 September 1989. At the Toronto (Bloor) station, approximately 47 mm of rainfall was recorded over an 8 hour period. The 47 mm of rainfall associated with this event represented 11 percent of the recorded 1989 seasonal rainfall (01 May to 31 October) and 28 percent of the recorded 1989 September/October rainfall. The largest events recorded in 1980 and 1990 were 37 mm over a 14 hour period (14 July 1980) and 49 mm over a 25 hour period (12 August 1990), respectively.

3.2 Sewer Outfalls

3.2.1 Wet Weather Flow Monitoring

As discussed in Chapter 2.0, continuous flow monitoring was undertaken at 8 locations. The location and characteristics of the flow monitoring sites has been presented in Figure 2.1 and Table 2.1. This monitoring was undertaken to characterize the nature of wet

weather discharges from various outfall types, provide information required for estimation of contaminant loadings, and verify the applicability of the City of Toronto QQS model.

Rainfall records from the Toronto (Bloor) climatological station indicate that 217 mm of rainfall (approximately 24 events) occurred over the 14 September 1990 to 15 December 1990 monitoring period. Furthermore, during this period, trace snowfall was recorded in November with the first snowfall event occurring 3 December (13 mm). Illustrated in Figure 3.2 are observed September through October flows at the following three monitoring sites:

- E5 - Storm;
- E11 - CSO; and
- TH15 - CSO.

As shown in Figure 3.2, the flow in a storm sewer system, such as E5, is highly responsive to rainfall events. Whereas, overflows from sewersheds serviced predominately by combined sewered areas, such as TH15, typically only occur as a result of significant rainfall. Over the September and October period of monitoring, 6 major overflow events occurred at TH15.

Provided in Table 3.4 is a summary of flow monitoring results and event runoff volumes. Difficulties were encountered in recording flows at E3 due to hydraulic conditions and equipment malfunctions. Therefore, minimal reliable flow data was obtained for this installation. Periodic difficulties were also encountered at TH12, W6, and W13. Reliable flow data was obtained for the other installations.

The accuracy of recorded flows is a function of site specific hydraulic conditions, procedure used to calibrate the equipment, quality of equipment installation and instrumentation, and frequency of site maintenance. For practical and safety reasons, detailed cross-checks of installed flow meter readings during wet weather conditions were not possible. However,

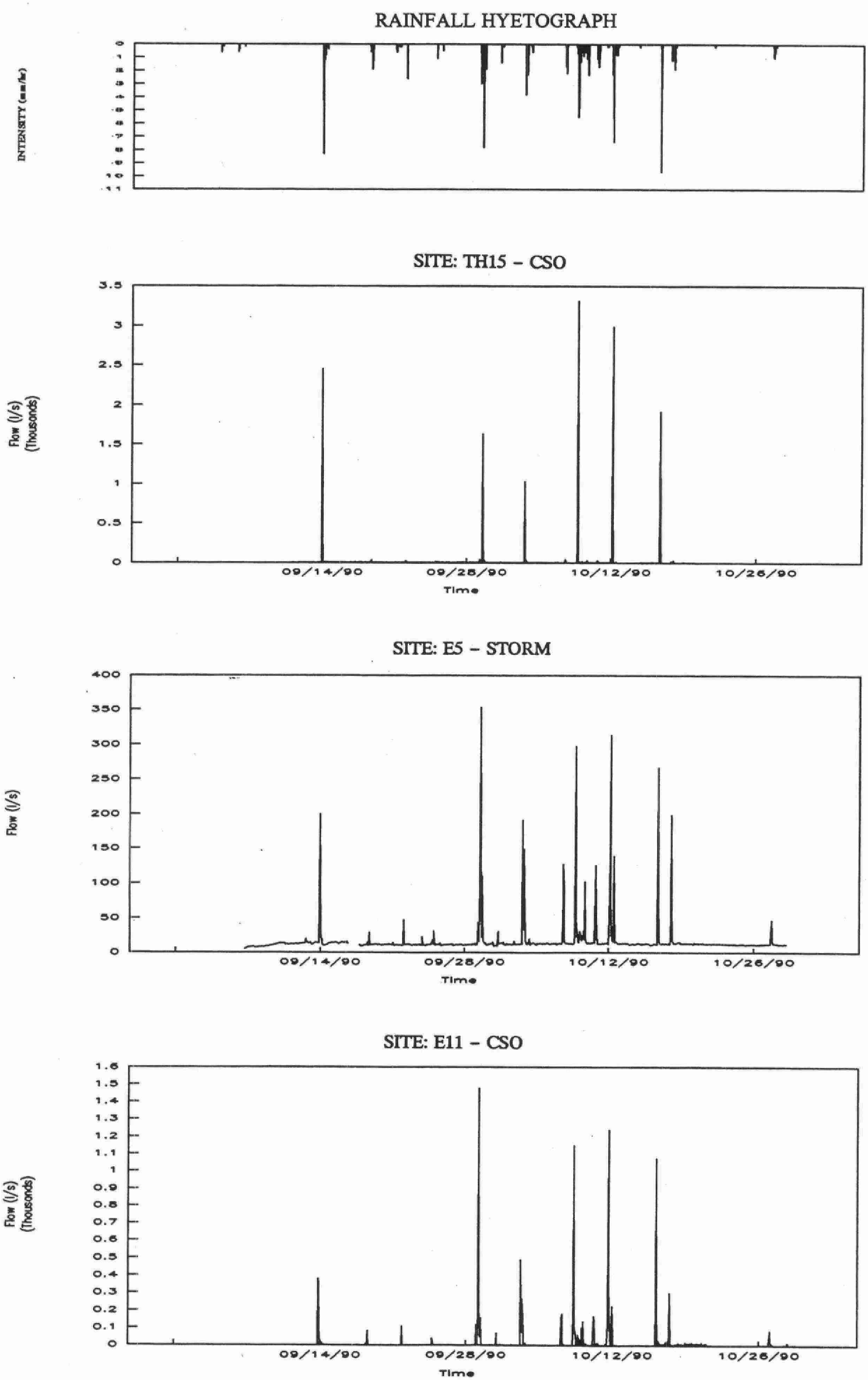


FIGURE 3.2 OBSERVED FLOWS (14 Sept. 1990 - 31 Oct. 1990)

recorded flow depths and velocities were checked periodically at each site, using physical measurements to estimate depth and a portable velocity meter (Montedoro-Whitney PVM-2) to estimate velocity. As required, each flow meter was calibrated accordingly. The accuracy of each instrument is a function of flow depth and velocity, with greater inaccuracy occurring for shallow flow depths. Instrumentation errors of approximately ±5 percent can be assumed based on the range of typical flows at the monitoring sites, installation conditions, and previous experience. The datalogger programming setups for the installed flow meters are provided in Appendix A.

3.2.2 QQS Model Application

Flow data was collected at the eight sites monitored, however, flow data was required for contaminant mass loading estimates for all sewer outfalls along the City of Toronto waterfront. This data was obtained through computer simulation of the City of Toronto sewerage network. The computer simulation component of this project was undertaken by staff of the City of Toronto Department of Works and the Environment with the Dorsch Quantity-Quality Simulation (QQS) model.

In 1978, the City of Toronto approved the application of the QQS model developed by Dorsch Consult for analysis of the City's interceptor behaviour within the sewerage system (Gore & Storrie *et al.*, 1991). Since 1978, the QQS model of the City of Toronto sewerage system has been regularly updated and undergone extensive calibration and verification as part of previous projects (Gore & Storrie, 1987; Gore & Storrie *et al.*, 1991). The most recent extensive study and model update of the network was completed in 1986 as part of the City of Toronto Trunk Sewer Review Study (Gore & Storrie, 1987). On an ongoing basis, updates are made to the model by the City of Toronto to account for improvements to the sewerage system. For instance, the model used in this study incorporated the Phase I Eastern Beaches Detention Tank.

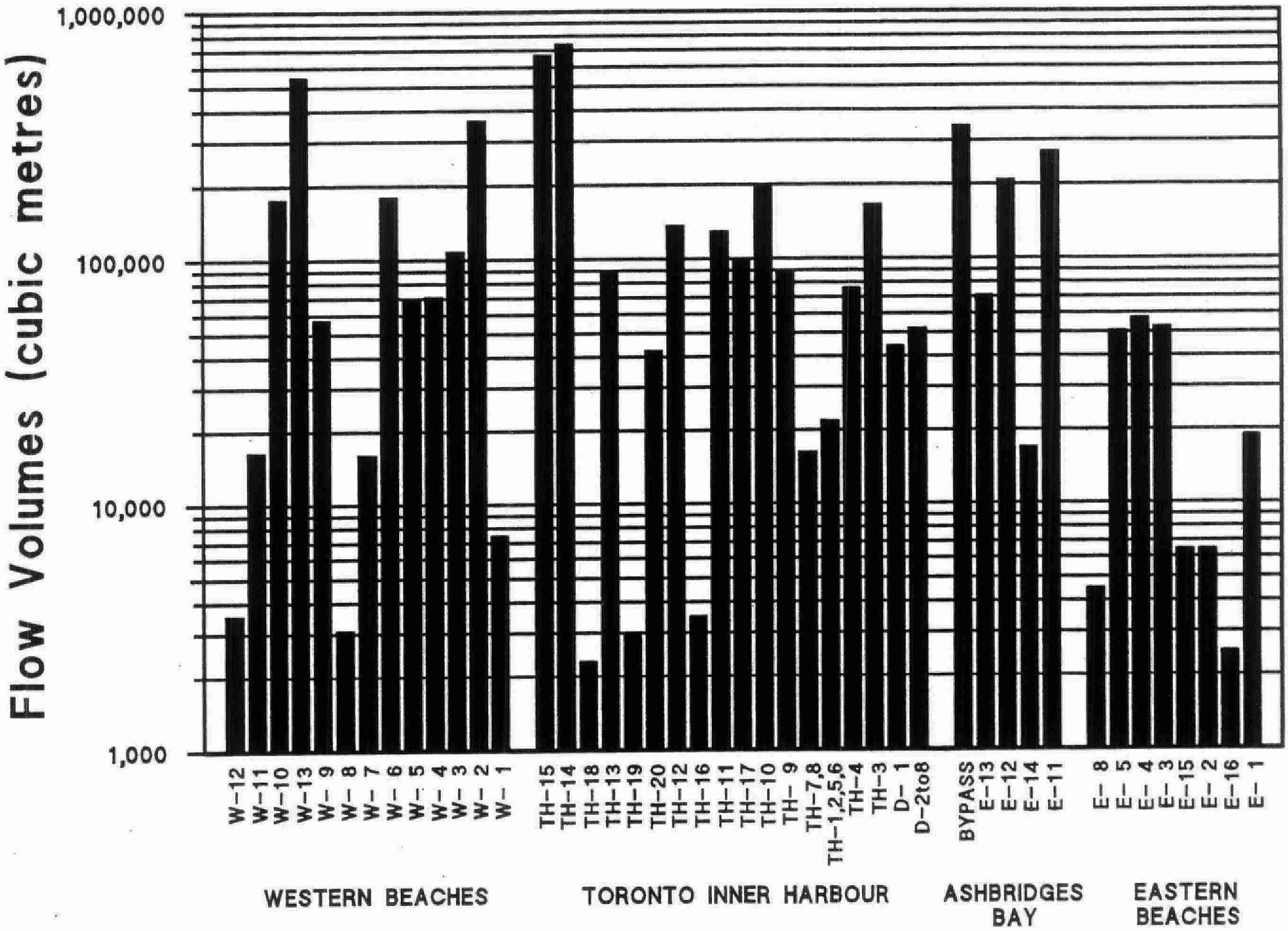
The QQS model can operate in either event or continuous mode. For this project, the QQS model was applied in continuous mode to estimate the volume of runoff discharged to the City of Toronto waterfront from each sewer outfall during the May through October period based on a typical year (1980) rainfall distribution.

To confirm applicability of the QQS model, the model was verified with flow monitoring data recorded as part of this project. The main focus of the verification procedure was a comparison of recorded and simulated runoff volumes. Summarized in Table 3.5 are observed and simulated runoff volumes for the months of September and October 1990. In general, it was found that the QQS model provided reliable estimates of flow volumes for the following sewer outfalls: E5; E11; and W5. Observed and simulated runoff volumes for the two month period were typically within 20 percent. Some discrepancies were found between observed and simulated volumes at outfalls discharging to the Toronto Inner Harbour (TH12 and TH15). In these cases, simulated volumes consistently overestimated those observed. This result is expected due to the complex and interconnected nature of the sewer system, and ongoing improvements to the interceptor system.

While some discrepancies may exist on a site-by-site basis, the City of Toronto has found that simulated volumes tend to match observed on an aggregate, or overall waterfront basis (I. Tarvydas, 1992).

3.2.3 Seasonal Flow Volumes

Presented in Figure 3.3 is a graphical summary of seasonal flow volumes (01 May through 31 October) from outfalls discharging to the City of Toronto waterfront. A tabular summary is provided in Table 3.6 and Table 3.7. The total seasonal volume of flow from these outfalls, based on the typical year, is approximately 5,300,000 cubic metres. This total includes 346,000 cubic metres estimated to bypass at the Main WPCP (see Section 3.3).



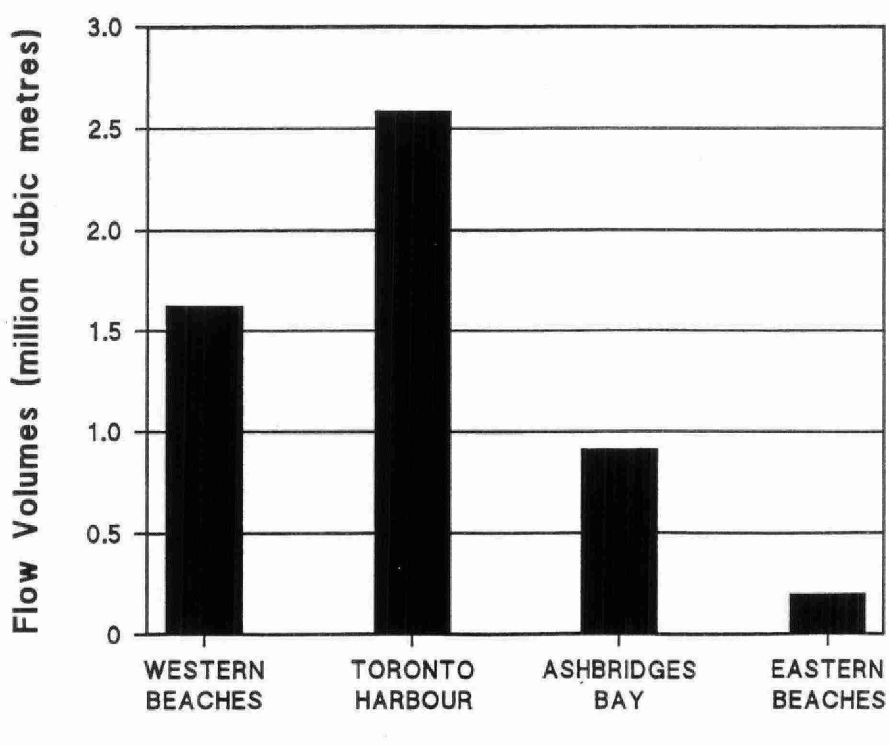


FIGURE 3.3 SUMMARY OF SEASONAL FLOW VOLUMES BY REGION

On a geographic basis, 48 percent of the total seasonal flow volume is discharged to the Toronto Inner Harbour from the TH and D series outfalls, 31 percent to the Western Beaches from the W series outfalls, 17 percent to the Ashbridges Bay region, and 4 percent to the Eastern Beaches.

Based on the information in this section, the Toronto Inner Harbour receives approximately half of the seasonal runoff volume to the Toronto waterfront, of which, a significant percentage is from outfalls which receive combined sewer overflows. With respect to the Eastern Beaches, the seasonal flow volume discharged to this region will decrease with the construction of the Phase II Eastern Beaches Detention Tank.

As shown in Figure 3.4, based on outfall type, 81 percent of the seasonal flow volume is discharged from outfalls which receive combined sewer overflows, 12 percent from outfalls which recieve storm water from separate storm sewers, and 7 percent from the Main WPCP Bypass.

The relative flow contribution by outfall type is presented for each of the four regions in Figure 3.5. While CSO designated outfalls contribute about 80 percent of the total wet weather flow volume to the entire waterfront, their relative contribution varies on a regional basis from about 30 percent in the Eastern Beaches to over 90 percent in the Western Beaches and Inner Harbour. Similarily, while the Metro Main WPCP contributes 7 percent of the total flow volume to the waterfront, its contribution to the Ashbridges Bay area is similar to the CSO contribution of about 40 percent.

Seasonal flow volumes on an outfall basis range from a low of less than 1,000 cubic metres at several of the Keating Channel (D series) outfalls to a high of 745,000 cubic metres (TH14). Approximately 56 percent of the seasonal flow volume is discharged by the following 6 outfalls:

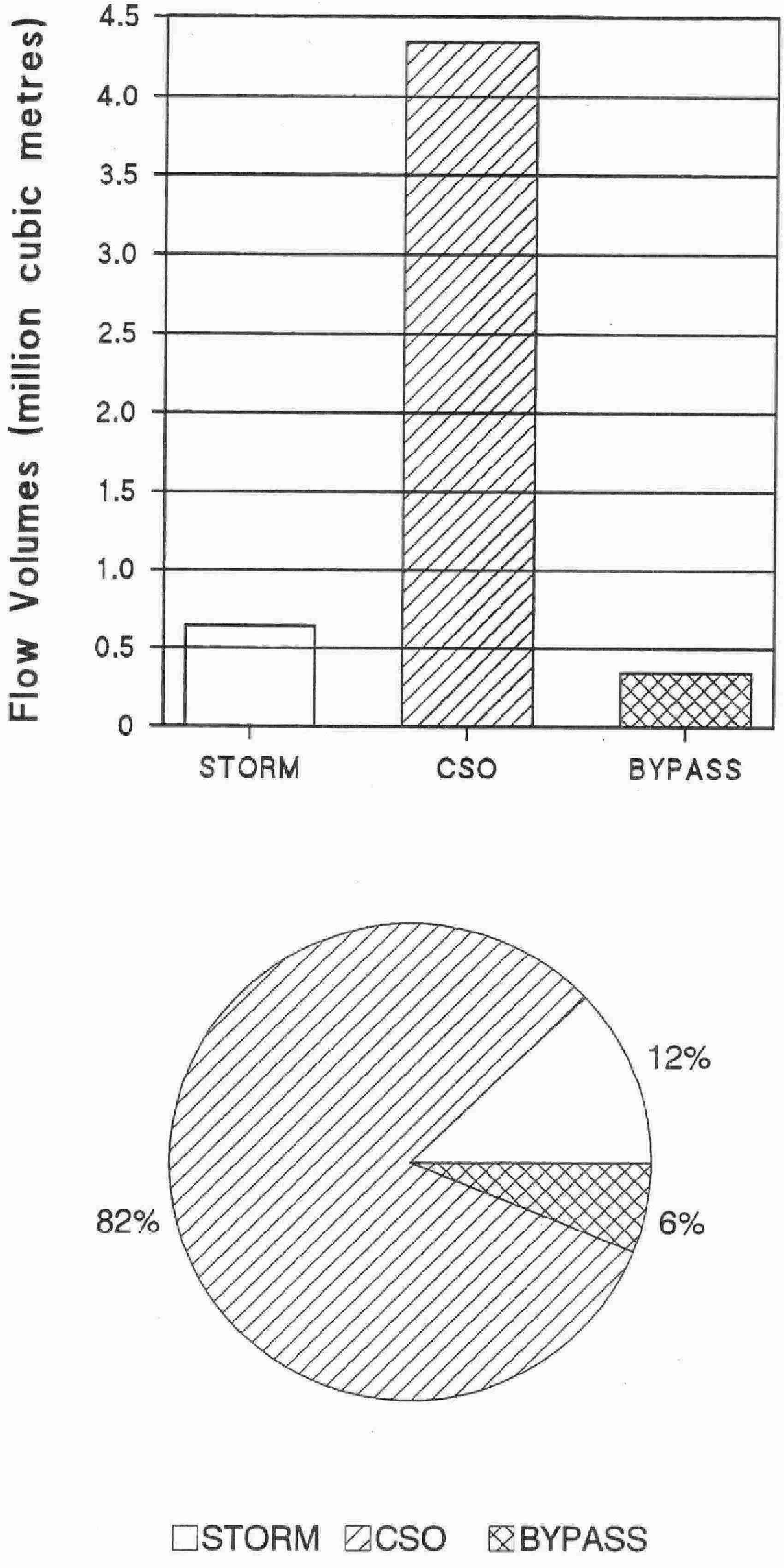


FIGURE 3.4 SUMMARY OF SEASONAL FLOW VOLUMES BY OUTFALL TYPE

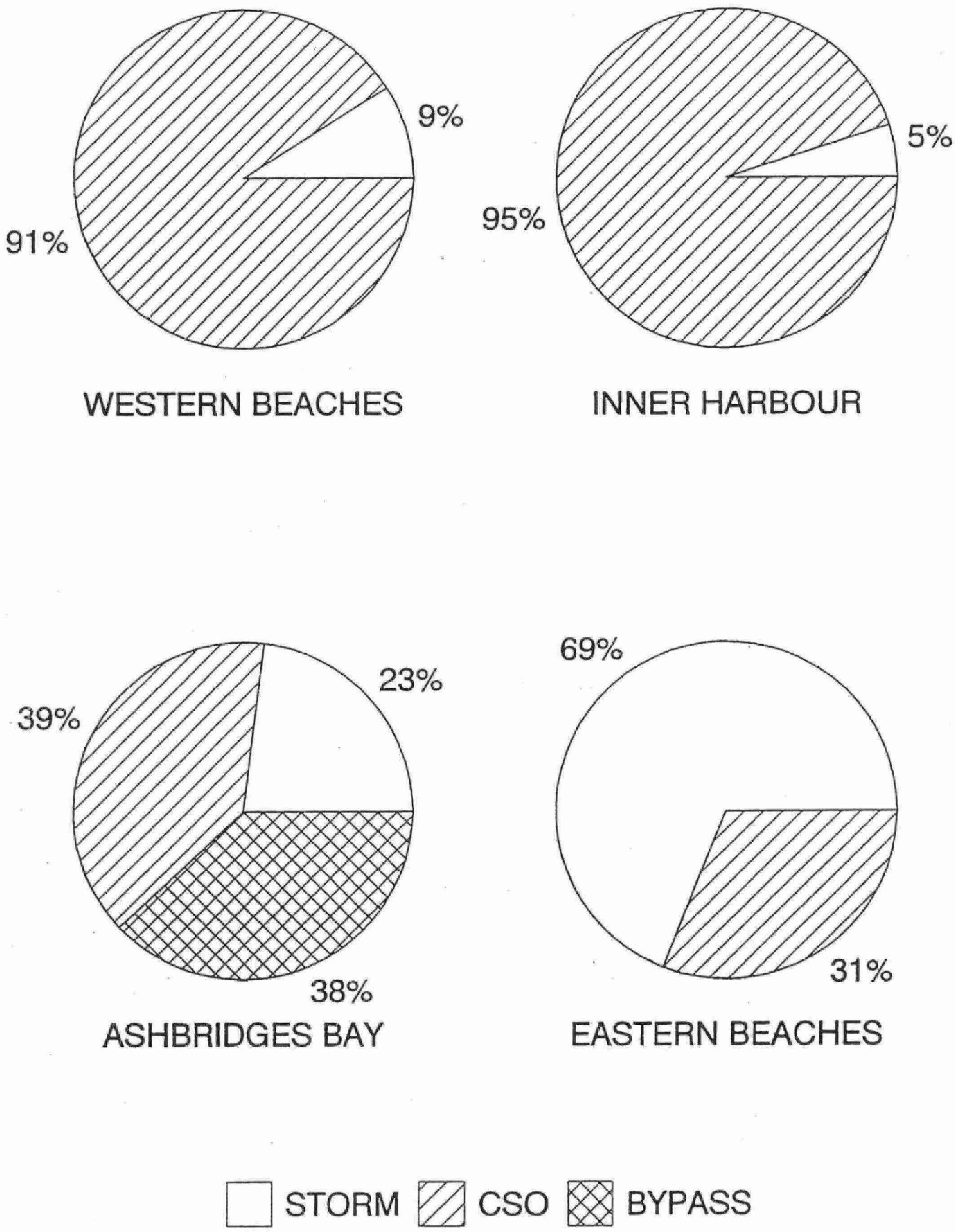


FIGURE 3.5 REGIONAL SUMMARY OF SEASONAL FLOW VOLUMES BY OUTFALL TYPE

- TH14 (CSO) - 14%;
- TH15 (CSO) - 13%;
- W13 (CSO) - 10%;
- W2 (CSO) - 7%;
- Main WPCP Bypass - 7%; and
- E11 (CSO) - 5%.

The information presented in this section represents seasonal flow volumes over the 01 May through 31 October period. The Phase I Metropolitan Toronto Waterfront Wet Weather Outfall Study (Paul Theil Associates Limited *et al.*, 1992) suggested that the seasonal flow volume from this summer/fall period represented approximately one third of the total annual runoff. A parallel study (Aquafor Beech Limited, 1994) is being conducted to evaluate in detail the relative seasonal (i.e., summer/fall versus winter/spring) flow volumes, contaminant concentrations, and contaminant mass loadings.

3.3 Main WPCP Bypass

The Main WPCP is located at Ashbridges Bay and receives sanitary and combined sewage from the Cities of York, Toronto, North York, and Scarborough, as well as the Borough of East York. The total sewerage area is approximately 26,570 hectares.

Under wet weather conditions, the plant secondary treatment capacity can be exceeded and combined sewage receiving primary treatment and chlorination is bypassed to the plant's outfall diffuser. Bypass volumes are estimated by plant operators as the Bypass is not instrumented with flow monitoring equipment. Water quality information on bypassed primary effluent is also limited. Attempts were made in both this and the Phase I project to sample and quantify the volume of bypassed primary effluent at the Main WPCP. In total, seven water quality samples were collected during the 1989 and 1990 monitoring periods. Flow monitoring was shown not possible due to difficulties encountered with equipment installations, hydraulic, structural, and instrumentation constraints.

Although flow monitoring was not possible, bypass volumes are estimated by plant operators based on duration of bypass. A summary of the 1989 and 1990 monthly bypass volumes as provided by the Metropolitan Toronto Works Department is presented in Table 3.8. Excluding occurrences as a result of construction activities, bypassing of primary effluent occurred 16 times in 1989 and 12 times in 1990. The typical duration of bypass events ranged from 0.5 to 10.0 hours.

Over 1989 and 1990, the average bypass event volume was 39,800 cubic metres and the average annual bypass volume was 557,300 cubic metres. Approximately 62 percent of the total 1989 and 1990 bypass volume occurred over the 01 May through 31 October period. This represents an average seasonal bypass volume of 346,000 cubic metres.

The occurrence and volume of bypassing is directly related to rainfall conditions. For instance, although there were more rainfall events in 1990 than in 1989 (see Table 3.2), there was less need to bypass as the events were typically smaller and of shorter duration. Therefore, a direct comparison of 1989 and 1990 bypass volumes to estimated typical year (1980) sewer outfall volumes is limited to establishing relative contributions likely to within an order of magnitude.

As identified in Section 3.2.3, the average 01 May through 31 October bypass volume of 346,000 cubic metres represents approximately 7 percent of the seasonal flow volume discharged to the City of Toronto waterfront by sewer outfalls and the Main WPCP Bypass. It is not known how representative this value is with respect to a long-term average as the frequency and volume of bypassing has been influenced by the on-going plant maintenance and upgrading of the sewerage system. However, this value of 346,000 cubic metres has been used to estimate seasonal contaminant mass loadings associated with the bypass of primary effluent at Main WPCP.

TABLE 3.1: LOCAL AES CLIMATOLOGICAL STATIONS

Station Name	Station Number	Period of Record Reviewed	Years of Data	Comments
Toronto (Bloor)	6158350	1937 - 1988	51	Operational. Longest period of record.
Ellesmere	6158520	1966 - 1988	22	Operational. May be removed.
Etobicoke	6158525	1963 - 1988	25	No longer in operation.
Greenwood	6158575	1966 - 1981	15	No longer in operation.
Island A	6158665	1971 - 1988	17	Operational Poor data.
Sherbourne	61587PP	1966 - 1979	13	No longer in operation.
Old Weston Road	6158764	1966 - 1988	22	Operational Poor data.

AES - Atmospheric Environment Service.

TABLE 3.2: COMPARISON OF SEASONAL RAINFALL CHARACTERISTICS (01 MAY TO 31 OCTOBER)

	Seasonal Depth (mm)	S.D.[1]	Mean Event Depth (mm)	S.D.	Mean Event Duration (hrs)	S.D.	Mean Event Intensity (mm/hr)	S.D.	Number of Events	S.D.
Historical Average										
Toronto (Bloor)[2]	400	104	7.2	1.4	5.8	0.7	1.3	0.3	59	7
1980	384		5.8		5.1		1.1		66	
1989	442		7.9		7.3		1.1		56	
1990	482		7.2		7.0		0.9		67	

Note: The above event statistics are based on hourly rainfall data and inter-event period of 6 hours (See Figure 3.1 for graphical presentation).
1 S.D. - Standard Deviation
2 Historical averages based on 42 years of useable records at the Toronto (Bloor) climatological station.

TABLE 3.3: COMPARISON OF MONITORING PERIOD RAINFALL DEPTHS[1]

Period	Rainfall Depth (mm)		
	Normal[2]	1989	1990
September	66.2	70.0	51.2
October	60.4	100.2	96.8
Total[3]	126.6	170.2 (+34%)	148.0 (+17%)

1. 01 September through 31 October.
2. 1951 - 1980.
3. The numbers in brackets represent percentage increase over the normal.

TABLE 3.4: SUMMARY OF FLOW MONITORING RESULTS AND EVENT RUNOFF VOLUMES

Event	Rainfall (mm)	Site and Observed Event Runoff Volumes (m^3)							
		W13	W6	W5	TH15	TH12	E11	E5	E3
14 September	15.6	4,610	BD	NE	10,560	350	3,220	1,320	BD
19 September	4.4	NE	BD	320	230	NE	590	130	BD
21 September	1.4	NE	NE	NE	NE	NE	NE	NE	BD
22 September	2.6	NE	NE	390	NE	NE	430	160	BD
25 September	1.5	NE	NE	130	NE	NE	210	NE	BD
29-30 September	22.6	3,880	BD	5,600	8,910	860	10,180	3,610	BD
1 October	1.4	NE	BD	150	NE	NE	310	130	80
4 October	13.2	620	NE	480	4,370	100	4,970	1,890	BD
7-9am October	22.2	BD	BD	4,200	430	BD	9,160	3,400	BD
9pm-11 October	15.4	BD	BD	2,830	2,840	BD	4,070	1,580	BD
12-13 October	21.6	7,210	BD	5,040	15,630	BD	10,220	2,970	BD
17 October	13.6	BD	BD	4,010	10,180	NE	5,640	1,680	BD
18 October	5.6	BD	NE	870	300	NE	2,170	1,120	BD
27-28 October	2.2	NE	BD	120	BD	NE	790	320	BD
4-5 November	27.2	NE	BD	6,130	BD	40	9,200	ND	2,690
9-10 November	1.8	NE	NE	NE	BD	NE	400	360	420
16 November	1.0	NE	NE	NE	BD	NE	210	80	210
21-22 November	7.8	NE	NE	920	BD	NE	2,160	350	BD
24 November	2.0	NE	NE	NE	BD	NE	570	120	BD
26-27 November	4.8	NE	BD	380	BD	NE	2,000	770	BD
28 November	0.8	NE	NE	NE	BD	NE	390	40	BD
3 December	25.2	790	NE	ND	BD	NE	12,750	6,190	BD
15 December	2.0	ND	ND	NE	ND	ND	ND	60	BD

ND - Data Not Available.
BD - Poor Quality Data.
NE - No Event.

TABLE 3.5: COMPARISON OF OBSERVED AND SIMULATED RUNOFF VOLUMES AT FLOW MONITORING SITES (September/October 1990)

Site[2]	Type	Runoff Volume (m^3)		
		Observed	Simulated	Difference[1]
E5	Storm	19,910	17,365	-13%
E11	CSO	56,610	68,140	+20%
W5	CSO	29,630	29,605	<1%
TH15	CSO	67,490	237,010	+251%

1. Percentage difference between simulated and observed September/October 1990 runoff volumes.
2. Continuous reliable flow monitoring data not obtained for W13, W6, TH12, and E3.

TABLE 3.6: SUMMARY OF SEASONAL RUNOFF VOLUMES[1]

Outlet No.	QQS Node	Location	Region	Outfall Type	Discharge (cu.m)
TH-14	7POR	Portland St.	Toronto Inner Harbour	CSO (29%)	744,880
TH-15	7BAT	Bathurst St.	Toronto Inner Harbour	CSO (69%)	673,000
W-13	6SUN	Glendale Ave.	Western Beaches	CSO (65%)	549,670
W-2	6STR	Strachan Ave.	Western Beaches	CSO (100%)	366,650
BYPASS	BYPASS	BYPASS[2]	Ashbridges Bay	Bypass	346,000
E-11	3326	E. of Coxwell Ave.	Ashbridges Bay	CSO (59%)	270,870
E-12	4416	E. of Woodfield Rd.	Ashbridges Bay	Storm	208,470
TH-10	7SHE	Sherbourne St.	Toronto Inner Harbour	CSO (34%)	194,070
W-6	6COW	Cowan Ave.	Western Beaches	CSO (74%)	180,110
W-10	6PAR	Parkside Dr.	Western Beaches	CSO (33%)	176,780
TH-3	4LES	Leslie St.	Toronto Inner Harbour	CSO (27%)	166,040
TH-12	7SIM	Simcoe St.	Toronto Inner Harbour	CSO (67%)	137,411
TH-11	7YON	Yonge St.	Toronto Inner Harbour	CSO (67%)	129,610
W-3	6WB4	CNE (Remembrance Dr.)	Western Beaches	Storm	108,430
TH-17	7JAR	Jarvis St.	Toronto Inner Harbour	CSO (98%)	98,453
TH-9	7PAR	Parliament St.	Toronto Inner Harbour	CSO (39%)	89,735
TH-13	7SPA	Spadina Ave.	Toronto Inner Harbour	CSO (50%)	89,018
TH-4	4CAR	Carlaw Ave.	Toronto Inner Harbour	CSO (31%)	76,543
E-13	4ASB	Near Woodfield Rd.	Ashbridges Bay	CSO (56%)	71,435
W-4	6EX2	C.N.E.	Western Beaches	CSO	71,224
W-5	6DUF	Dufferin St.	Western Beaches	CSO (80%)	69,243
E-4	3442	Maclean Ave.	Eastern Beaches	CSO (96%)	57,527
W-9	6RON	Roncesvalles Ave.	Western Beaches	CSO (80%)	57,451
E-3	3410	Balsam Ave.	Eastern Beaches	Storm	52,826
D-2..8	4IH2	Keating Channel	Keating Channel	Storm	52,211
E-5	3419	Glen Manor Dr.	Eastern Beaches	Storm	50,974
D-1	7CHR	Cherry St.	Keating Channel	CSO (59%)	44,277
TH-20	7321	Rees St.	Toronto Inner Harbour	Storm	42,590
TH-1,2,5&6	4IH4	Ship Channel	Toronto Inner Harbour	Storm	21,880
E-1	3429	Nursewood Rd.	Eastern Beaches	Storm	18,974
E-14	3315	Coxwell Ave.	Ashbridges Bay	CSO (100%)	17,010
W-11	6WB2	Colbourne Lodge Dr.	Western Beaches	Storm	16,400
TH-7&8	4IH3	W. end Poulson St. & Commissioners St.	Toronto Inner Harbour	Storm	16,296
W-7	6WB3	Jameson Ave.	Western Beaches	Storm	15,967
W-1	7WB5	Queens Quay W.	Western Beaches	Storm	7,499
E-15	3436	Willow Ave.	Eastern Beaches	Storm	6,472
E-2	3421	Silver Birch Ave.	Eastern Beaches	Storm	6,452
E-8	3311	Kenilworth Ave.	Eastern Beaches	CSO (100%)	4,524
W-12	8WB1	Ellis Ave.	Western Beaches	Storm	3,553
TH-16	7317	Bay St.	Toronto Inner Harbour	Storm	3,518
W-8	6WIL	Wilson Park Rd.	Western Beaches	CSO (99%)	3,109
TH-19	7315	Queens Quay W.	Toronto Inner Harbour	Storm	2,985
E-16	3423	Neville Park Blvd.	Eastern Beaches	Storm	2,504
TH-18	7312	Queens Quay W.	Toronto Inner Harbour	Storm	2,263
Total Volume					5,324,904

1. 01 May 1980 To 31 October 1980.
2. Estimated seasonal bypass volume based on 1989 and 1990 data.
3. The percentage in brackets for the CSO outfalls represents the percentage of the sewershed area serviced by combined sewers.

TABLE 3.7: SUMMARY OF SEASONAL RUNOFF VOLUMES BY REGION

Region	Storm Outfall (m^3)	CSO Outfall (m^3)	WPCP Bypass (m^3)	Total (m^3)
Western Beaches	151,800	1,474,200	0	1,626,000
Inner Harbour	141,700	2,443,000	0	2,584,700
Ashbridges Bay	208,500	359,300	346,000[1]	913,800
Eastern Beaches	138,200	62,100	0	200,300
Total	640,200	4,338,600	346,000	5,324,800

1 - 1989 & 1990 seasonal average

TABLE 3.8: SUMMARY OF METRO MAIN WPCP MONTHLY BYPASS VOLUMES

Month	Estimated Volume	
	1989[1]	1990[2]
January	0	0
February	0	100
March	0	0
April	25,000	0
May	43,800	116,200
June	87,500	0
July	16,200	0
August	118,100	45,300
September	113,000	0
October	107,600	48,300
November	176,300	21,300
December	0	195,900
Total:	687,500	427,100

1. Number of bypass events in 1989 was 16.
2. Number of bypass events in 1990 was 12.

4.0 CONTAMINANT CONCENTRATION CHARACTERISTICS

4.1 Field Program Summary

A target collection of 10 samples per site was established to provide a reasonable measure of variability within the water quality data set. This target of 90 samples in total (i.e., 10 samples from 9 sites) was acheived for conventional parameters and heavy metals. However, considerably fewer samples (approximately 50) were obtained for the analysis of trace organics. This was largely due to the collection of insufficient sample volume for some events due to small event size and/or malfunctioning of equipment. For instance, if less than 16 litres was collected, the analysis of trace organic contaminants was not possible and the available sample volume was submitted for conventional analyses. In addition, the onset of winter conditions precluded the continued collection of representative samples.

4.2 Statistical Techniques

The flow and contaminant concentrations associated with urban discharges are quite variable during a given event, between events, and between sites. To characterize concentration characteristics, data summaries and analyses have been undertaken using storm event values. An event mean concentration (EMC) for the contaminants has been chosen as the primary water quality statistic. The EMC can be defined as the total contaminant mass discharge divided by the total runoff volume for a given storm event (U.S. EPA, 1983). In this study, EMCs are based on flow weighted composite samples collected as part of the field program. Occasionally, the mean of the EMCs for the pooled data set of either a given site or outfall type has been referred to as the average event mean concentration (AEMC).

The following statistical analyses were performed using the compiled water quality database to assess contaminant concentration characteristics associated with wet weather discharges from sewer outfalls and the Main WPCP Bypass:

- identification of frequency of detection (Section 4.3);
- comparison of EMC and runoff volume (Section 4.4);
- determination of the mean and variability of EMCs by outfall type (Section 4.5); and
- comparison of AEMCs by outfall type (Section 4.5).

Prior to undertaking the above analyses, the water quality database was augmented with data collected from two monitoring sites which were part of the Phase I Metropolitan Toronto Wet Weather Outfall Study: E11 and the Main WPCP Bypass.

Many of the contaminant concentration data sets used in this study are left-censored (i.e., contain data at or below the analytical detection limit). In general, the frequency of detection associated with the data sets can be categorized as follows:

- non-detected (0% detection);
- rarely detected (less than 20% detection); and
- frequently detected (greater than 20% detection).

For this study, estimates of contaminant mass loadings have not been provided for parameters with a frequency of detection less than 20 percent. This is due to the uncertainty associated with the estimate of a mean value when few values are above the detection limit.

Statistical summaries of the contaminant concentration data sets included an estimate of the mean (AEMC) and a measure of variability described by the 95 percent confidence interval (i.e., the AEMC would lie within the confidence interval 95 times out of 100). Typically, the confidence interval for the AEMC is much narrower than the range of values within a given data set. As many of the data sets were left-censored, the statistical evaluation of these data sets required the use of non-traditional techniques.

Probability distribution estimation (PDE) techniques were used to estimate the mean and associated confidence interval for the data sets containing censored data. These techniques use the probability distribution of the non-censored data (i.e., data above the detection limit) to estimate the statistical properties of the entire data set. One of these techniques, the maximum likelihood estimation (MLE) method, is widely accepted for the statistical description of left-censored water chemistry data (Cohen, 1959; Gilbert 1987; El-Sharaawi and Dolan, 1989). The MLE method was one technique used in this study. It provides an estimate of the mean and standard deviation of the data set by using estimates of the statistical properties of the non-censored data. It is recommended for use when up to 80 percent of the distribution is censored and where there is a minimum of 3 to 5 non-censored values.

Another PDE technique, used in the analysis of data sets which did not meet the criteria for the application of the MLE method, involved using linear regression on the probability distributions of the non-censored data. The regressions were used to generate estimates of the censored data which were used in the estimation of the mean and corresponding confidence interval by traditional methods. This approach was generally used when 80 percent to 90 percent of the data set consisted of censored values.

In addition, a more traditional approach such as substituting a fraction (generally 1/2) of the analytical detection limit value for those values which were at or below the detection limit was used when the data characteristics did not permit application of the two PDE techniques. Typically, this approach was used on data sets where application of the MLE was not possible because estimates of the variance were large and in cases where only 1 or 2 non-censored data points were available. Confidence intervals were not presented because they were biased by the substituted data.

Contaminant mass loading estimates were then made after the following analyses were undertaken:

- the probability distribution function was determined for the concentration data examined;

- the relationship between EMC and event flow volume was examined for representative data sets;

- the AEMC for each site and outfall type was determined; and

- comparison of the AEMCs was undertaken by outfall type (i.e., Storm, CSO, Bypass).

4.2.1 Probability Distribution of Water Quality Concentrations

In order to apply the PDE techniques, a probability distribution needed to be selected which best characterizes the contaminant concentration data sets. Two probability distributions commonly used to characterize data sets include the normal distribution and the log-normal distribution. The applicability of both of these distributions was assessed.

An analysis of the individual data sets and of the pooled data sets was made graphically by plotting the cumulative probability distribution of water quality parameters assuming both a normal and a log-normal distribution. Examples are provided in Figure 4.1 of the cumulative log-normal probability distributions for total suspended solids, iron, and dieldrin. Included in Figure 4.1 is information from both the pooled storm sewer and combined sewer data sets. As shown in this figure, the log-normal distribution adequately represents the variability in EMC between storm events and sites. This result is typical of many of the data sets.

A second method for selecting a probability distribution to describe a data set is to examine values of the third and fourth moments of the distribution (i.e., skewness and kurtosis). For instance, a data set which can be reasonably described by the normal distribution will have

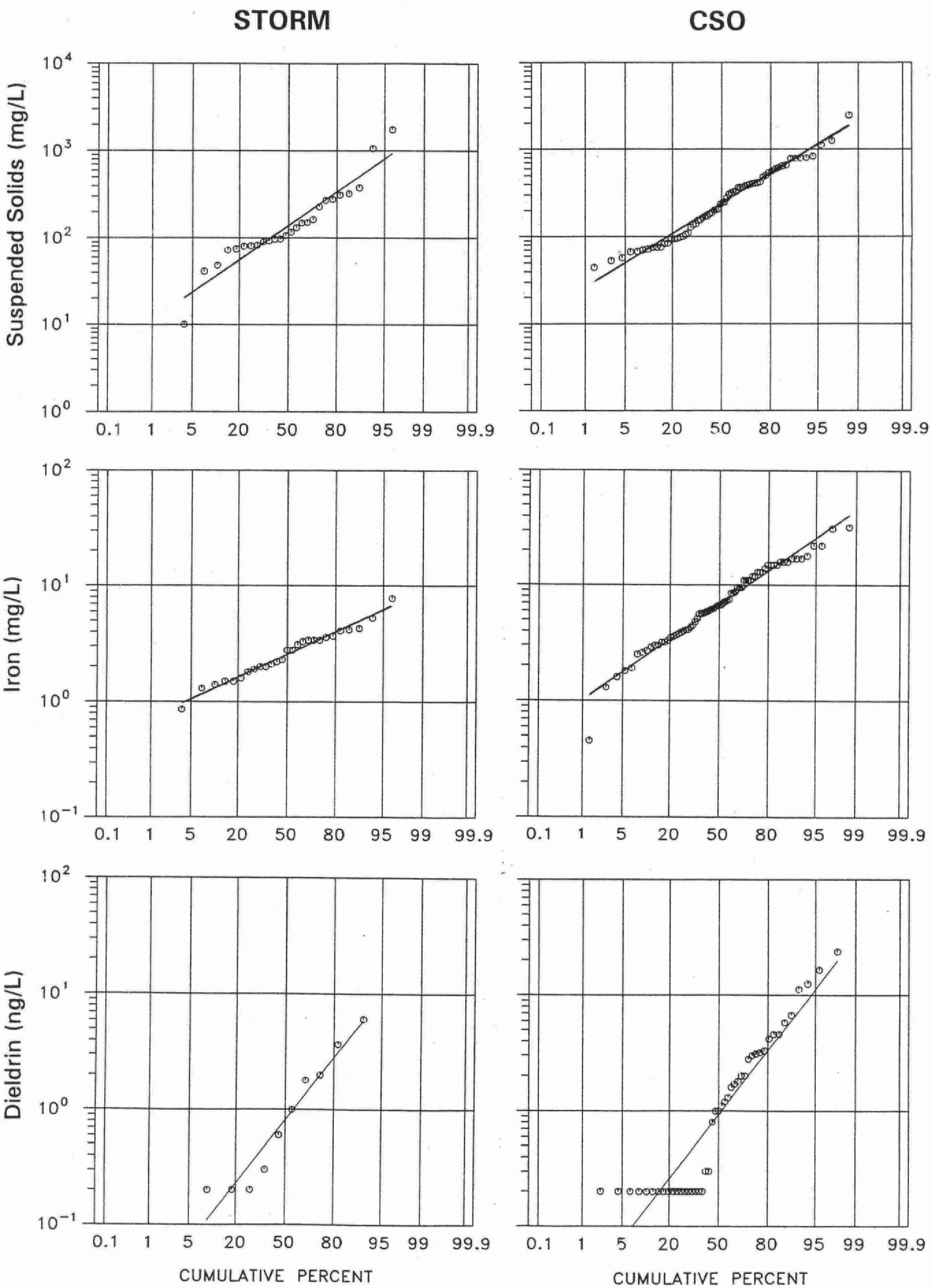


FIGURE 4.1 REPRESENTATIVE LOG-NORMAL PROBABILITY DISTRIBUTIONS

a value for skewness of approximately 0 and value for kurtosis of approximately 3. By inspection, these conditions were found to be satisfied when the data was log transformed.

Consistent with results of the Phase I Metropolitan Toronto Wet Weather Outfall Study (Paul Theil Associates Limited, 1992) and the Nationwide Urban Runoff Program (NURP) completed by the U.S. Environmental Protection Agency (1983), the log-normal distribution has been used as the basis to characterize EMCs. Accordingly, the 95% confidence intervals of the mean concentration m_x can be expressed as follows:

$$m_x \left[\exp \left(\frac{-1.96}{\sqrt{n}} \sigma_{\ln_x} \right) \right] \leq m_x \leq m_x \left[\exp \left(\frac{1.96}{\sqrt{n}} \sigma_{\ln_x} \right) \right]$$

where:

x is a concentration data set comprised of $x_1, x_2, x_3, \ldots. x_n$ *values*

$m_x = \exp \left(\frac{1}{2} \sigma^2_{\ln_x} + m_{\ln_x} \right)$

m_x = *arithmetic mean of data set x*

$m_{\ln_x}$ = *arithmetic mean of* $\log_e$ *transformed data*

$\sigma_{\ln_x}$ = *standard deviation of* $\log_e$ *transformed data*

While other studies, such as NURP, have summarized mean contaminant concentrations based on a geometric mean, the mean values in this study are based on an arithmetic mean of the log-transformed data set. The implications of this are discussed in Section 4.7.

4.3 Frequency of Detection

Summarized in Table 4.1 is a complete list of the analyzed parameters, detection limit, total number of samples submitted for analysis, and percentage of data above the analytical detection limit. The frequency of detection has been summarized in Table 4.1 by outfall type. Conventional water quality parameters, such as total suspended solids, nutrients, and bacteria had the highest detection frequency. These parameters were detected in typically 100 percent of the samples collected.

Detection frequencies for heavy metals generally exceeded 20 percent. Less frequently detected parameters were arsenic and selenium. Parameters such as barium, copper, iron, manganese, lead, and zinc were detected in 100 percent of the samples. Other frequently detected parameters included aluminum, nickel, chromium, mercury, and cadmium.

In general, the non-conventional trace organic parameters were detected less frequently and at lower concentrations than both the conventional parameters and heavy metals. Furthermore, the organochlorine pesticides, chlorobenzenes, and PCBs were detected less frequently than the PAHs. Frequencies of detection for the pooled data sets indicate that most compounds were detected and that 46 of 53 parameters were detected in more than 20 percent of the samples collected for at least one outfall type. The most frequently detected trace organics were PAHs and included pyrene, naphthalene, phenanthrene, and fluoranthene. The detection frequencies of these PAH parameters generally exceeded 80 percent.

Overall, the following parameters were detected in more than 20 percent of the samples collected at either one of the sewer outfall types or the Main WPCP Bypass:

General Chemistry

- Alkalinity
- Cyanide - avl. unfilt. react.
- Cyanide - free unfilt. react.
- Chemical Oxygen Demand
- Ammonium - tot. filt. react.
- Nitrates - tot. filt. react.
- Nitrite - filt. react.
- Total Kjeldahl Nitrogen
- Phenolics - unfilt. react.
- Total Phosphorus
- Total Suspended Solids
- Residue - total
- Solvent Extractables

Bacteriology

- *Escherichia Coliform* MF
- Fecal Coliform MF
- Fecal Streptococcus MF
- *Pseudomonas Aeruginosa* MF

Heavy Metals (Unfiltered Totals)

- Aluminum
- Arsenic
- Barium
- Beryllium
- Cadmium
- Chromium
- Copper
- Iron
- Mercury *
- Manganese
- Nickel
- Lead
- Silver
- Zinc

Organochlorine Pesticides/Chlorobenzenes/PCBs

- Aldrin
- alpha-bhc *
- gamma-bhc (Lindane) *
- Chlordane-alpha
- Chlordane-gamma
- PP-DDD *
- PP-DDE *
- PP-DDT *
- Hexachlorobutadiene
- Hexachlorobenzene *

- Dieldrin *
- DMDT-Methoxychlor
- Endosulfan-Sulphate
- Endosulfan-II
- Heptachlorepoxide
- Oxychlordane
- Heptachlor
- OP-DDT *
- PCB total *
- Octachlorostyrene
- Pentachlorobenzene
- Trichlorotoluene 2-6-A
- Trichlorobenzene 1-2-3
- Trichlorobenzene 1-2-4
- Trichlorobenzene 1-3-5
- Tetrachlorobenzene 1-2-3-4
- Tetrachlorobenzene 1-2-4-5
- Tetrachlorobenzene 1-2-3-5

Polynuclear Aromatic Hydrocarbons

- Acenaphthene
- Acenaphthylene
- Anthracene *
- Benzo (A) Anthracene *
- Benzo (A) Pyrene *
- Benzo (B) Fluoranthene
- Chrysene
- DiBenzo (AH) Anthracene
- Fluoranthene
- Fluorene
- Benzo (G,H,I) Perylene *
- Indeno (1,2,3-CD) Pyrene
- Naphthalene
- Perylene *
- Phenanthrene *
- Pyrene
- 1-Methylnaphthalene
- 2-Methylnaphthalene

The parameters with asterisks (*) have been identified as critical pollutants in the Great Lakes basin ecosystem (Environment Canada *et al.*, 1991) and/or are on the primary list of candidate substances for ban or phase-out (Ontario Ministry of the Environment, 1992).

Concentration characteristics and contaminant mass loadings have not been provided for parameters with a frequency of detection less than 20 percent.

4.4 Comparison of Event Mean Concentration and Runoff Volume

The Nationwide Urban Runoff Program (U.S. EPA, 1983) and the Phase I Metropolitan Toronto Wet Weather Outfall Study (Paul Theil Associates Limited *et al.*, 1992) found no significant relationship between EMC and runoff volume. This infers that concentration and runoff volume are independent and that contaminant loadings can be determined as the product of the EMC and runoff volume. In addition, this suggests that results from water quality sampling programs and subsequent EMC comparisons are not expected to be influenced due to any bias in the average size of events which occurred over the monitoring period.

A comparison of EMC and runoff volume was made in this study to verify the applicability of results as presented in the Nationwide Urban Runoff Program (NURP) and the Phase I study. For this assessment, data was reviewed for each of the two outfall types and a minimum of 3 representative parameters from each of the five parameter groups. To assess the relationship between EMC and runoff volume, graphical comparisons were made and correlation coefficients determined using linear regression analysis (i.e., log (EMC) versus runoff volume).

Illustrated in Figure 4.2 and Figure 4.3 are comparisons of EMC and runoff volume at two sewer outfalls (E5 - Storm, W5 - CSO) for total suspended solids, fecal coliforms, iron, zinc, gamma-bhc, and benzo (A) pyrene. In general, the data in these figures supports the NURP and Phase I finding that EMC is independent of runoff volume. Furthermore, no significant relationships were identified in the regression analysis. Correlation coefficients were typically less than 0.4.

For the combined sewer site (W5), a trend was noted in the graphical comparisons of increased EMC with runoff volume for large events. Although not reflected in the regression analysis, this trend was visually apparent for 9 of the 15 parameters reviewed.

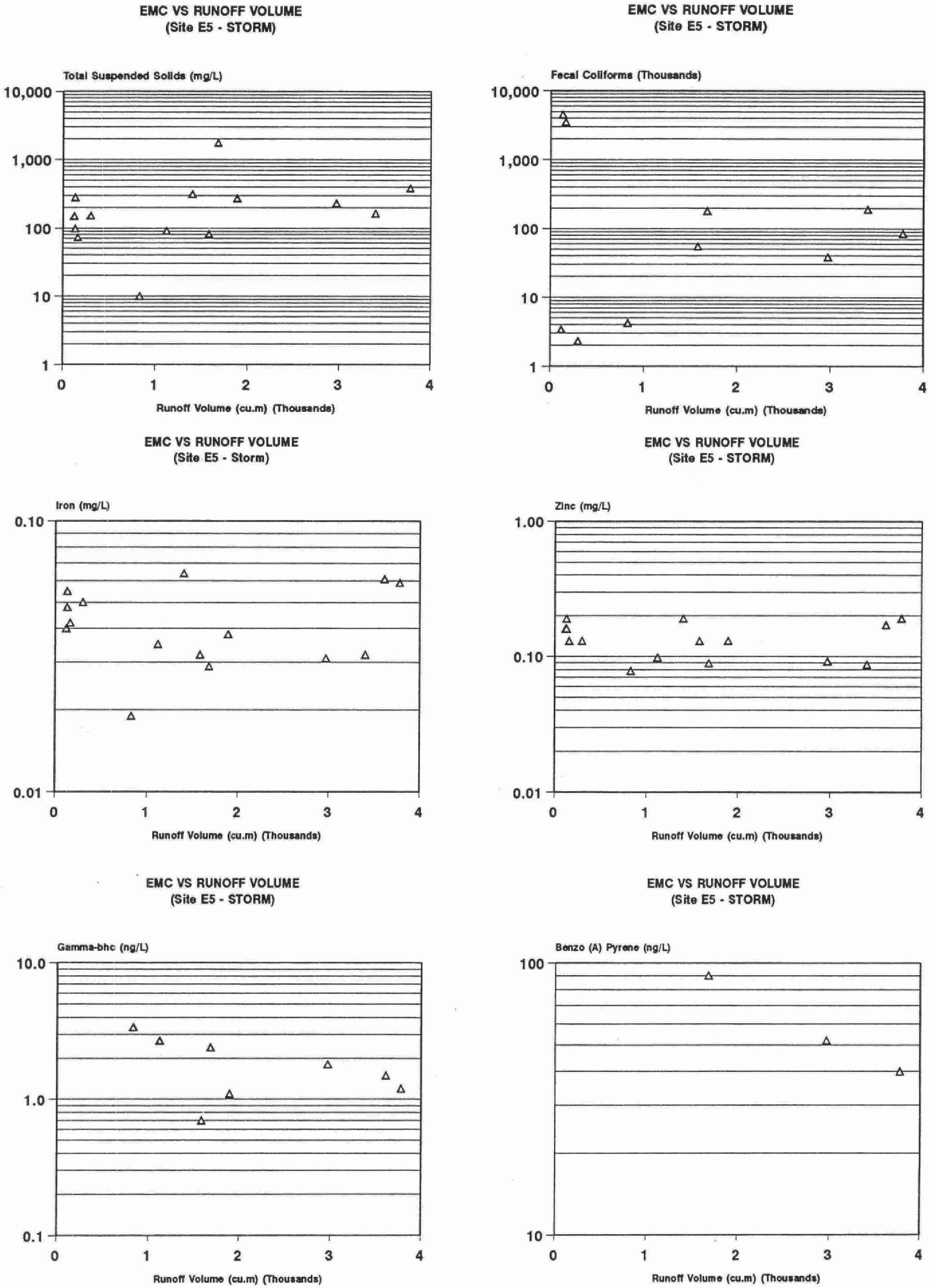
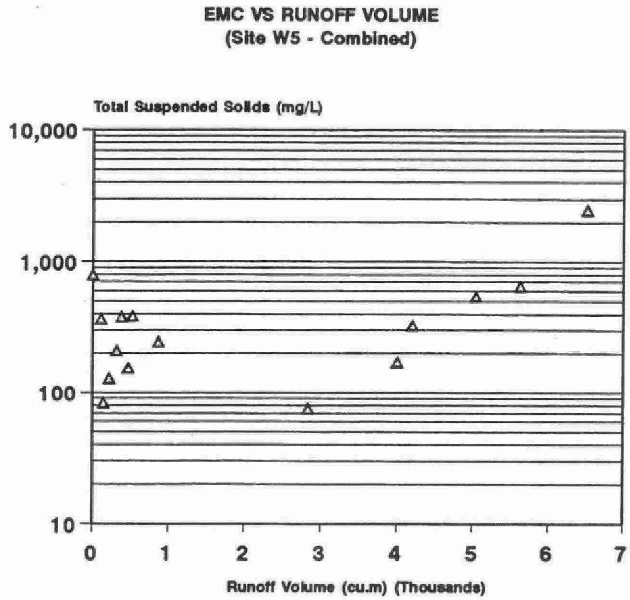
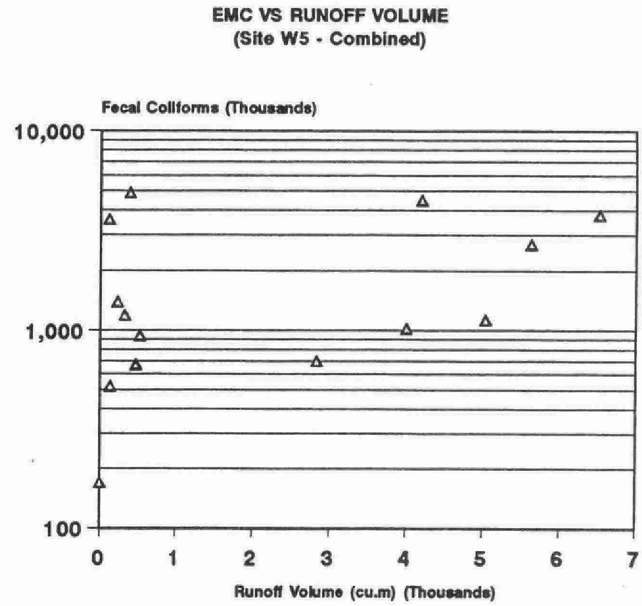
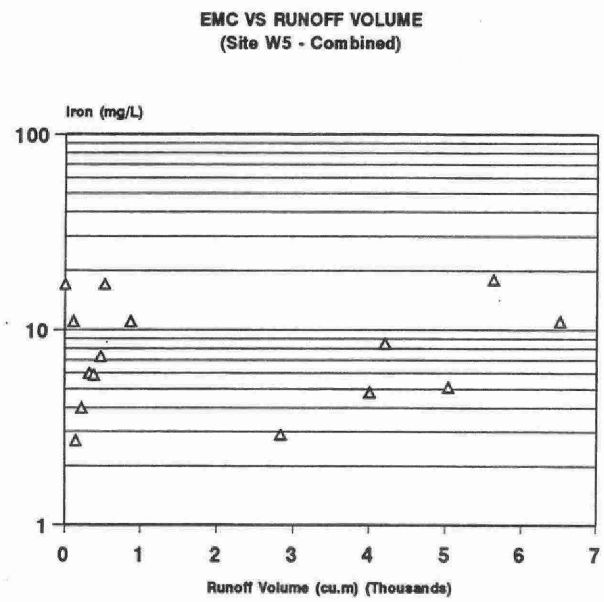
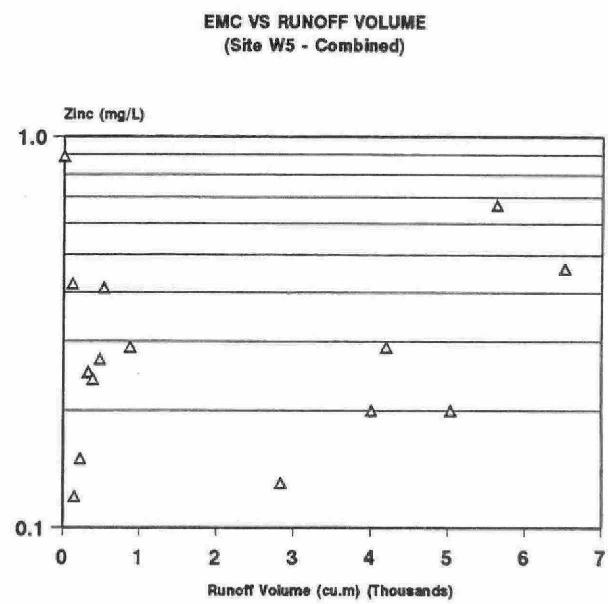


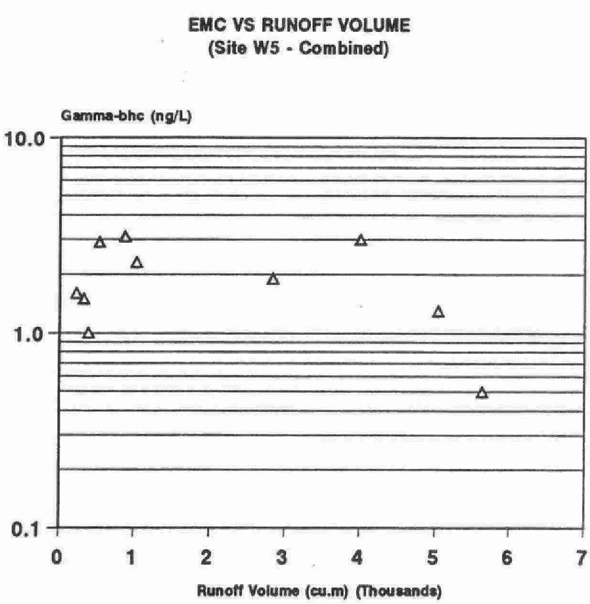
FIGURE 4.2 COMPARISON OF EMC AND RUNOFF VOLUME - STORM SEWER OUTFALLS











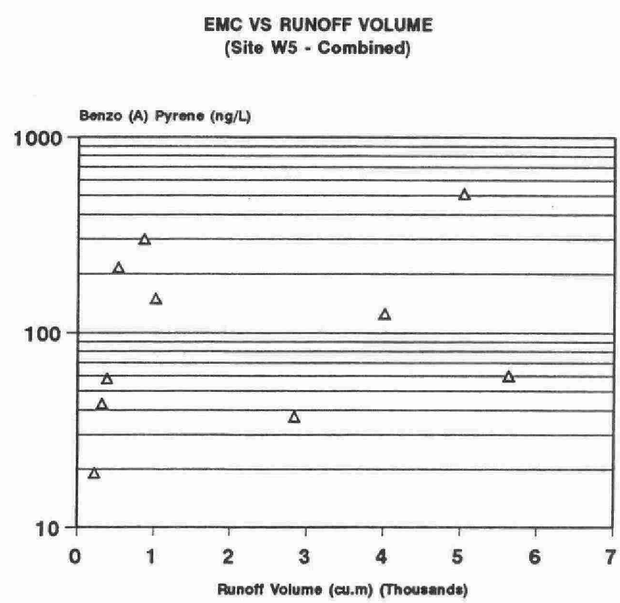


FIGURE 4.3 COMPARISON OF EMC AND RUNOFF VOLUME - OUTFALLS RECEIVING COMBINED SEWER OUTFALLS

The exceptions were the trace organic parameters dieldrin, gamma-bhc, trichlorobenzene, benzo (A) pyrene, fluoranthene, and phenanthrene.

4.5 Comparison of Event Mean Concentration and Outfall Type

Mean contaminant concentrations (AEMCs) are presented in this section based on outfall type (i.e., Storm, CSO, and Bypass). Comparison between AEMCs for sewer outfalls based on land use has not been made due to the interconnected nature of the City of Toronto sewerage system and difficulty in selecting representative outfalls with a distinct singular land use. Previous studies, such as NURP and the Phase I Metropolitan Toronto Wet Weather Outfall Study, have reported AEMCs for storm sewer outfalls based on land use. As discussed in Section 2.1, sites selected in the monitoring phase of this study were selected based on sewer system type and mix of land uses serviced. These sites were considered typical of outfalls discharging to a given region of the waterfront.

Consistent with characteristics of the City of Toronto sewerage system, the water quality data sets were pooled to determine AEMCs by outfall type. A detailed summary of AEMCs and 95 percent confidence intervals is provided in Table 4.2 by outfall type. Where applicable, the Provincial Water Quality Objective (PWQO) or Guideline (PWQG) and Metropolitan Toronto Sewer Use By-Law limits have also been included. It should noted that while PWQOs have been derived as receiving water based standards for the protection of aquatic life, they are used in this report as a benchmark by which the significance of the discharge is gauged. The Metropolitan Toronto Sewer Use Bylaw limits apply to discharges from industrial areas to the sewerage system. Typically, the By-Law limits for discharges to the sewerage system are within a factor of two to five of PWQOs, reflecting the fact that only a modest amount of dilution is available before acceptable ambient concentrations are acheived.

Illustrated in Figure 4.4 through Figure 4.7 are graphical presentations of AEMCs and confidence intervals for representative parameters from each parameter grouping. The data

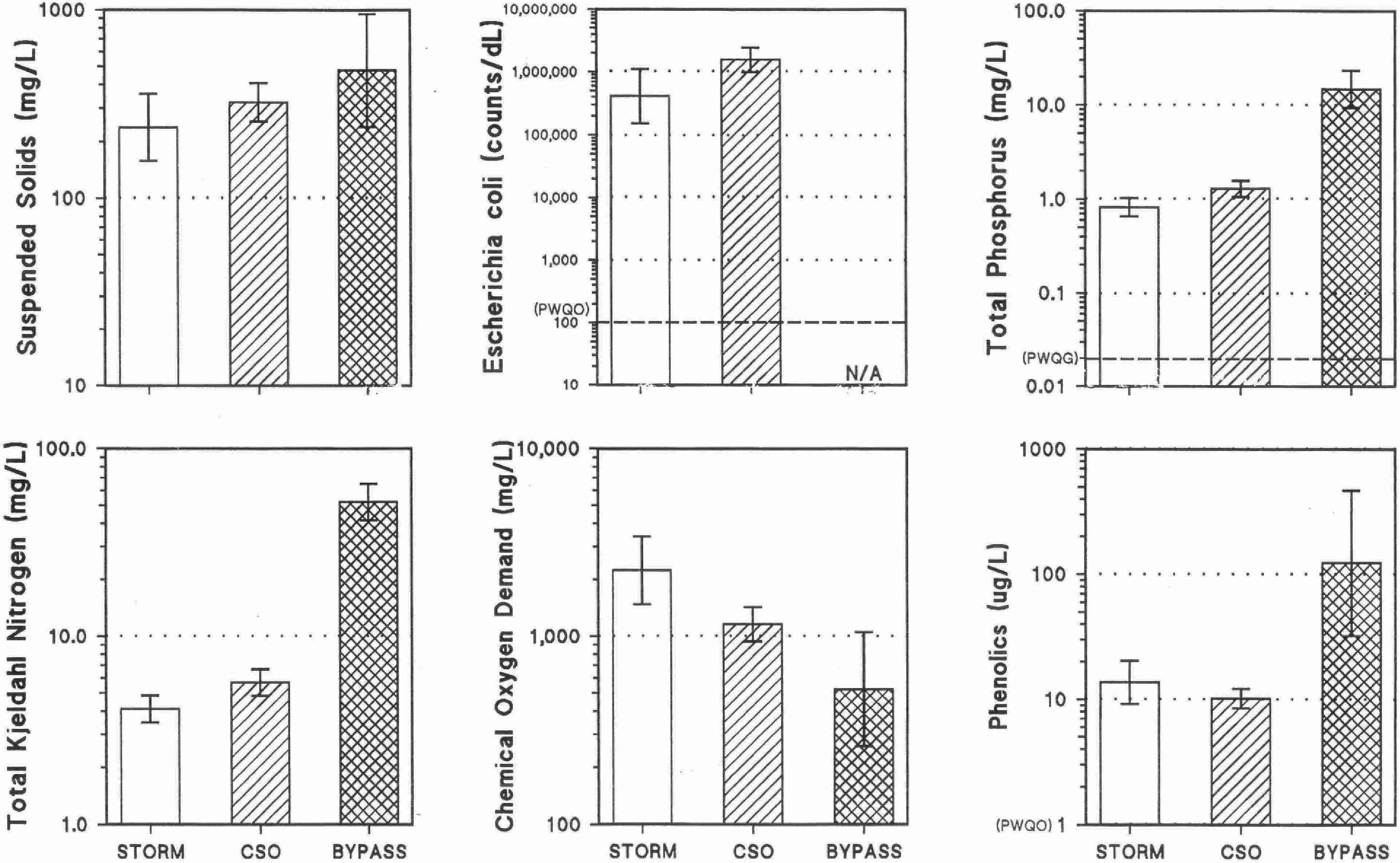


FIGURE 4.4 MEAN CONTAMINANT CONCENTRATIONS WITH THE 95% CONFIDENCE INTERVAL FOR CONVENTIONAL PARAMETERS

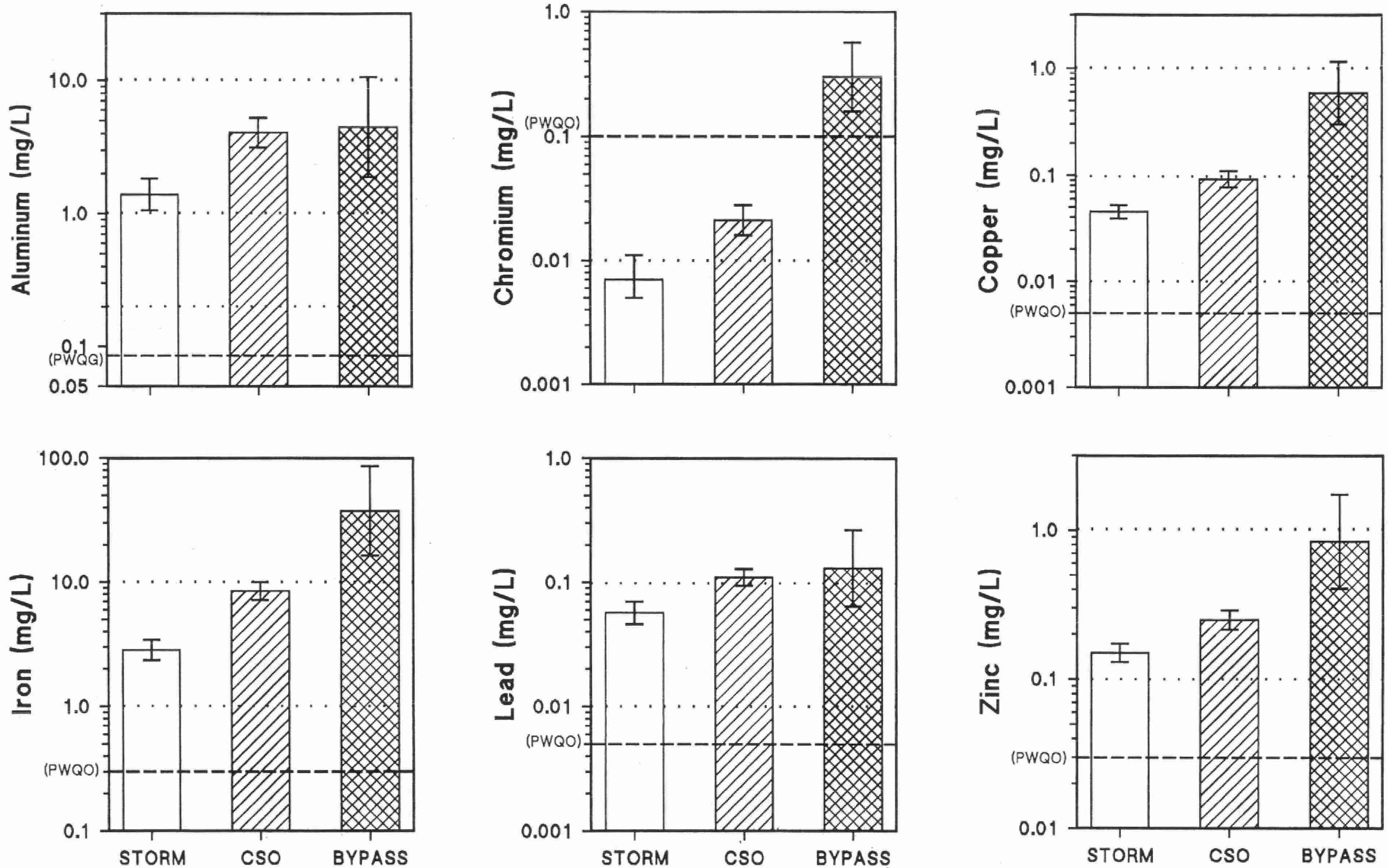


FIGURE 4.5 MEAN CONTAMINANT CONCENTRATIONS WITH THE 95% CONFIDENCE INTERVAL FOR HEAVY METALS

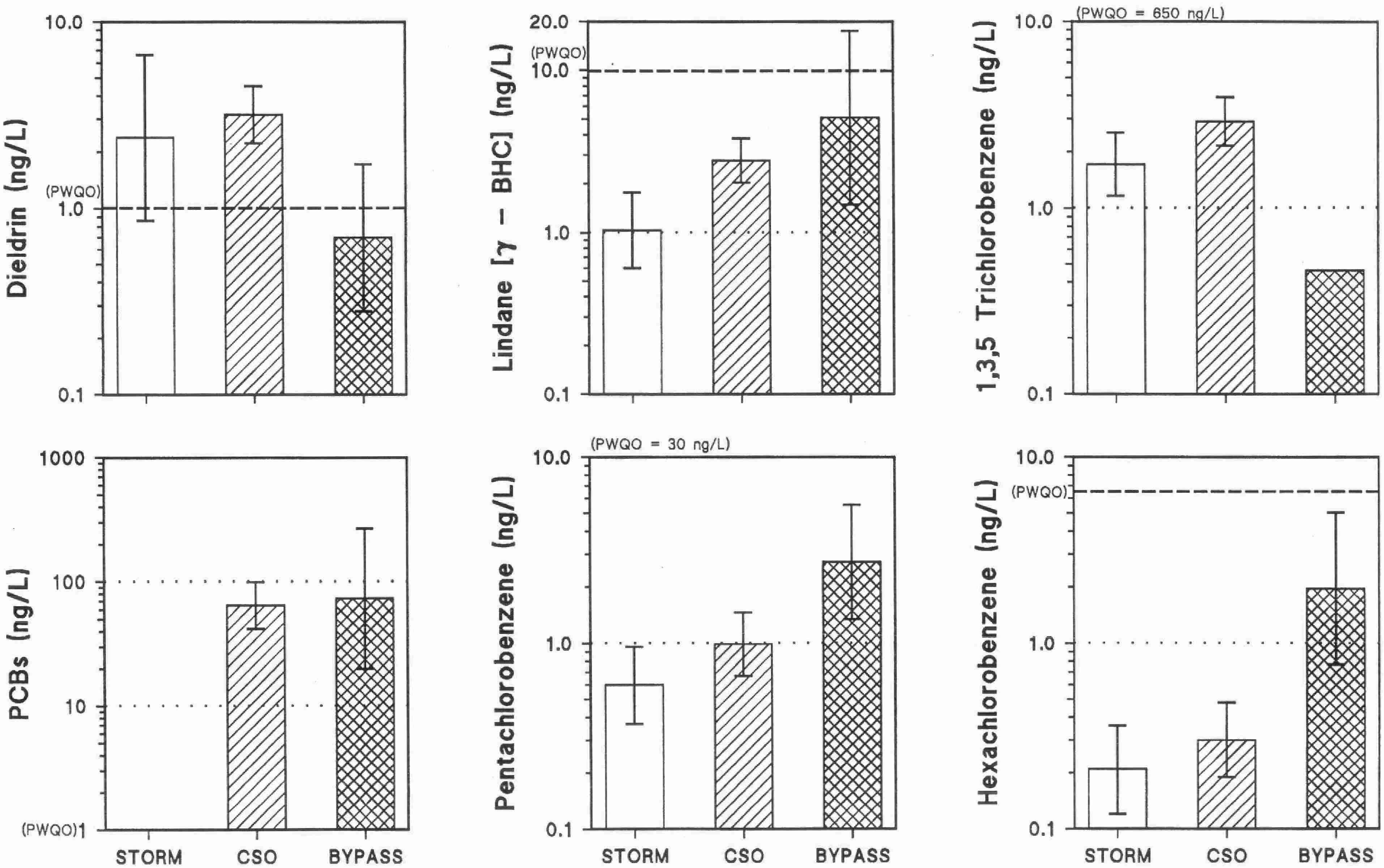


FIGURE 4.6 MEAN CONTAMINANT CONCENTRATIONS WITH THE 95% CONFIDENCE INTERVAL FOR ORGANOCHLORINE/CHLOROBENZENE PESTICIDES AND PCBs

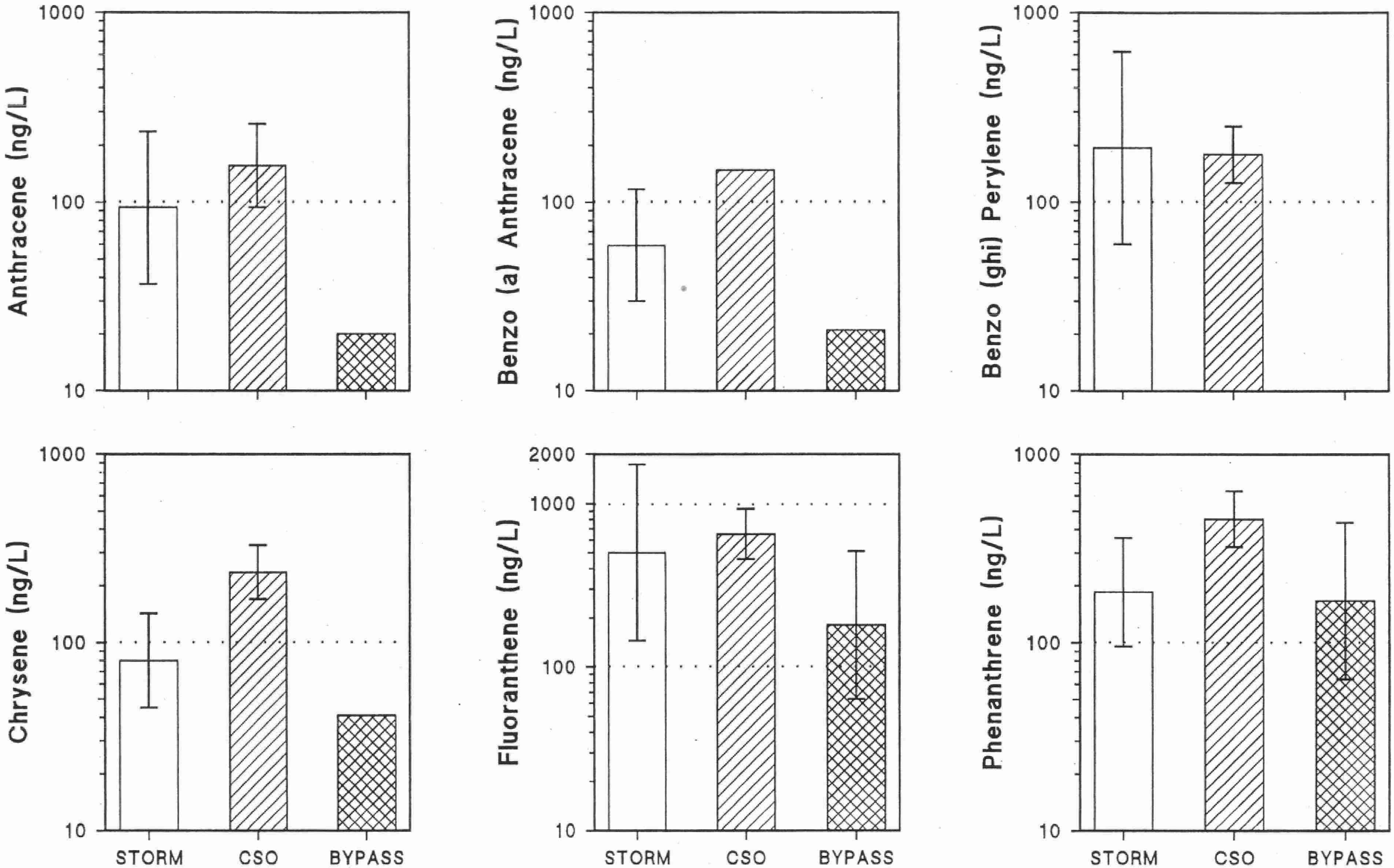


FIGURE 4.7 MEAN CONTAMINANT CONCENTRATIONS WITH THE 95% CONFIDENCE INTERVAL FOR POLYCYLIC AROMATIC HYDROCARBONS (PAHs)

has been presented using a logarithmic scale as the range of EMCs is typically over several orders of magnitude. In both Figure 4.4 and Table 4.2, no concentration information is presented for the bacteriological parameters as accurate sampling data for these respective parameters is unavailable for bypassed primary effluent. The sampling location at the Metro Main WPCP was situated upstream of the chlorination point prior to discharge to the submerged outfall. Therefore, concentration of bacteriological parameters in the bypassed primary effluent will be significantly lower at the point of discharge to the waterfront than at the sampling point.

Mean contaminant concentrations for storm sewer and combined sewer outfalls were found to be similar for most parameters. By graphical inspection, significant differences exist when the lower limit of an AEMC confidence interval for one outfall type is greater than the upper limit of an AEMC confidence interval for another outfall type. Conversely, the AEMCs are considered similar if the confidence intervals overlap. Concentrations in combined sewer overflows were found to be significantly higher than storm sewer discharges for:

General Chemistry

- Alkalinity
- Total Phosphorus

Bacteriology

- *Pseudomonas Aeruginosa* MF

Heavy Metals

- Aluminum
- Barium
- Chromium
- Copper
- Iron
- Mercury
- Manganese
- Lead
- Zinc

Organochlorine Pesticides and Chlorobenzenes

- Gamma-bhc (Lindane)
- PP-DDD

PAHs

- Benzo (B) Fluoranthene
- Chrysene

Conversely, concentrations in storm sewer discharges were found to significantly higher than discharges from outfalls receiving combined sewer overflows for:

General Chemistry

- Chemical Oxygen Demand

With respect to the Metro Main WPCP Bypass, mean contaminant concentrations of the conventional parameters (eg. total suspended solids, nutrients, and bacteria) and heavy metals were significantly higher than those of the sewer outfalls. This is attributed to the significant sanitary sewage component in the bypassed primary effluent. Mean concentrations of the trace organics (eg. organochlorine pesticides, chlorobenzenes, PCBs, and PAHs) are generally similar to those of the sewer outfalls.

Summarized below is a list of parameters where the AEMCs for the Bypass are significantly higher than those for either the Storm or CSO outfalls.

General Chemistry

- Alkalinity
- Ammonium
- Cyanide
- Phenolics
- Total Kjeldahl Nitrogen
- Total Phosphorus
- Solvent Extractables

Heavy Metals

- Barium
- Cadmium
- Chromium
- Copper
- Iron
- Mercury
- Silver
- Zinc

Organochlorine Pesticides and Chlorobenzenes

- Hexachlorobenzene
- Trichlorobenzene

4.6 List of Parameters which have Applicable Criteria and Higher Frequency of Detection

A list of parameters analyzed in this study for which PWQO/Gs or Metropolitan Toronto Sewer Use By-Law limits are available and which were frequently detected are presented in Table 4.3. Outfall types with AEMCs in excess of the PWQO/G's or the Sewer Use By-Law (if PWQO/G is not available) are identified in Table 4.3 by the shaded boxes. While PWQOs have been derived as receiving water based standards for the protection of aquatic life, they also provide a benchmark by which the significance of a discharge can be gauged.

As presented in the table, the parameter groups most frequently in exceedance of the PWQO/G's or the Metro Sewer Use By-Law were the general chemistry, bacteriology, and heavy metals. Parameters exceeding these criteria for all three outfall types include phenolics, total phosphorus, total suspended solids, fecal coliforms, aluminum, cadmium, copper, iron, lead, silver, and zinc. Of the trace organic parameters, dieldrin was frequently detected in excess of the PWQO in sewer outfalls only.

A number of priority pollutants were detected at low concentrations. As discussed in Section 4.3, PWQOs are not available for many of these parameters and PWQOs are not

always exceeded for other parameters (eg. lindane). However, many of these parameters found at a high frequency of detection have been identified by the Ontario Ministry of the Environment and Energy as candidate substances for ban or phaseout.

The frequency of detection by outfall type for parameters on the primary list of candidate substances for ban or phase-out (Ontario Ministry of the Environment, 1992) was as follows:

	PARAMETER	STORM	CSO	BYPASS
•	Mercury	77%	90%	100%
•	alpha-bhc	100%	81%	71%
•	gamma-bhc	90%	84%	86%
•	Dieldrin	80%	74%	71%
•	OP-DDT	90%	74%	57%
•	PCB total	10%	67%	57%
•	PP-DDD	80%	79%	29%
•	PP-DDE	70%	88%	86%
•	PP-DDT	90%	77%	29%
•	Hexachlorobenzene	60%	49%	100%
•	Anthracene	100%	93%	71%
•	Benzo (A) Anthracene	100%	92%	67%
•	Benzo (A) Pyrene	60%	94%	20%
•	Benzo (G,H,I) Perylene	80%	93%	14%
•	Perylene	38%	18%	0%
•	Phenanthrene	100%	95%	100%

4.7 Comparison of Event Mean Concentrations with Other Studies

4.7.1 Storm Sewer Discharges

Comparisons are provided in Table 4.4 between AEMCs from this study (Phase II) to those reported in the Phase I study, Nationwide Urban Runoff Program (NURP), and Upper Great Lake Connecting Channels Area study (UGLCC). A thorough comparison for all parameters is not possible because shorter parameter lists were used in the NURP and UGLCC studies. Provided in Table 4.4 is a comparison of AEMCs for separated storm sewer discharges. In comparison to the Phase I study, the contaminant concentrations reported in this study are typically higher for the general chemistry and bacteriology parameters, similar for both the heavy metals and organochlorine pesticides, and lower for the PAHs.

In general, the Phase II AEMCs lie either within the range or one order of magnitude of those reported by NURP and UGLCC. It should be noted that the AEMCs as reported in the Phase I and Phase II studies are based on the arithmetic mean of the log transformed data sets. Whereas, AEMCs as reported by the Nationwide Urban Runoff Program (NURP) are based on geometric means. The arithmetic mean of the log-transformed data sets, as determined by the Maximum Likelihood approach, for example, will tend to provide higher AEMCs for small data sets with high variability than would a geometric mean.

4.7.2 Combined Sewer Discharges

Comparisons are provided in Table 4.5 between AEMCs for combined sewer discharges from this study (Phase II) to those reported in the Phase I study, NURP, UGLCC, and Toronto Area Watershed Management Strategy (TAWMS). In comparison to the Phase I study, the Phase II AEMCs are typically higher with the exception of several trace organics

(i.e., gamma-bhc (Lindane), dieldrin, hexachlorobenzene, and anthracene). Generally, both the Phase II and Phase I AEMCs are within the same order of magnitude. In addition, with the exception of chemical oxygen demand and total suspended solids, the Phase II and Phase I AEMCs for conventional and heavy metal parameters fall approximately within the range of data as reported by NURP, TAWMS, and UGLCC.

TABLE 4.1: SUMMARY OF FREQUENCY OF DETECTION BY OUTFALL TYPE

PARAMETER	MOE CODE	UNITS	MDL	STORM		CSO		MAIN WPCP BYPASS	
				# SAMPLES	% DETECT	# SAMPLES	% DETECT	# SAMPLES	% DETECT
GENERAL CHEMISTRY									
Alkalinity	ALKT	mg/L	0.02	24	100%	82	100%	5	100%
Cyanide - avl. unfilt. react.	CCNAUR	mg/L	0.001	23	57%	67	66%	5	100%
Cyanide - free unfilt. react.	CCNFUR	mg/L	0.001	22	18%	68	7%	5	40%
Chemical Oxygen Demand	COD	mg/L	2	25	100%	80	100%	5	100%
Ammonium - tot. filt. react.	NNHTFR	mg/L	0.05	25	64%	79	56%	6	100%
Nitrates - tot. filt. react.	NNOTFR	mg/L	0.05	23	78%	78	72%	5	40%
Nitrite - filt. react.	NNO2FR	mg/L	0.005	25	92%	78	91%	5	100%
Total Kjeldahl Nitrogen	NNTKUR	mg/L	0.05	25	100%	78	100%	6	100%
Phenolics - unfilt. react.	PHNOL	ug/L	0.2	24	100%	66	100%	5	100%
Total Phosphorus	PPUT	mg/L	0.02	25	100%	78	100%	6	100%
Total Suspended Solids	RSP	mg/L	0.3	25	100%	74	100%	5	100%
Residue - total	RST	mg/L	1	25	100%	74	100%	5	100%
Solvent Extractables	SOLSXT	mg/L	0.5	18	72%	56	82%	5	100%
BACTERIOLOGY									
Escherichia Coliform MF	ECMF	CNT/100 mL	4	17	100%	66	100%	5	100%
Fecal Coliform MF	FCMF	CNT/100 mL	4	17	100%	66	100%	5	100%
Fecal Streptococcus MF	FSMF	CNT/100 mL	4	17	100%	66	100%	5	100%
Pseudomonas Aeruginosa MF	PSAMF	CNT/100 mL	2	16	100%	66	100%	5	100%
HEAVY METALS[1]									
Aluminum	ALUT	mg/L	0.005	26	100%	81	100%	5	100%
Arsenic	ASUT	mg/L	0.001	26	19%	82	16%	5	40%
Barium	BAUT	mg/L	0.005	26	100%	82	100%	5	100%
Berylium	BEUT	mg/L	0	26	27%	82	46%	5	40%
Cadmium	CDUT	mg/L	0	26	73%	82	74%	5	100%
Chromium	CRUT	mg/L	0.001	26	81%	82	89%	5	100%
Copper	CUUT	mg/L	0.0001	26	100%	82	100%	5	100%
Iron	FEUT	mg/L	0.01	26	100%	82	100%	5	100%
Lead	PBUT	mg/L	0.005	26	100%	82	100%	5	100%
Mercury	HGUT	ug/L	0.02	26	77%	82	90%	5	100%
Manganese	MNUT	mg/L	0.001	26	100%	82	100%	5	100%
Nickel	NIUT	mg/L	0.001	26	85%	82	98%	5	80%
Selenium	SEUT	mg/L	0.001	26	4%	82	10%	5	0%
Silver	AGUT	mg/L	0.001	26	35%	82	57%	5	100%
Zinc	ZNUT	mg/L	0.001	26	100%	82	100%	5	100%

TABLE 4.1: SUMMARY OF FREQUENCY OF DETECTION BY OUTFALL TYPE (cont'd)

PARAMETER	MOE CODE	UNITS	MDL	STORM		CSO		MAIN WPCP BYPASS	
				# SAMPLES	% DETECT	# SAMPLES	% DETECT	# SAMPLES	% DETECT
ORGANOCHLORINE PESTICIDES/CHLOROBENZENES/PCBs									
Aldrin	P1ALDR	ng/L	0.1	10	0%	43	56%	7	29%
Alpha-bhc	P1BHCA	ng/L	0.1	10	100%	43	81%	7	71%
Beta-bhc	P1BHCB	ng/L	0.1	10	0%	43	12%	7	14%
Gamma-bhc (Lindane)	P1BHCG	ng/L	0.1	10	90%	43	84%	7	86%
Chlordane - alpha	P1CHLA	ng/L	0.2	10	90%	43	81%	7	57%
Chlordane - gamma	P1CHLG	ng/L	0.2	10	90%	43	70%	7	57%
Dieldrin	P1DIEL	ng/L	0.2	10	80%	43	74%	7	71%
DMDT - Methoxychlor	P1DMDT	ng/L	0.4	10	50%	43	47%	7	0%
Endrin	P1ENDR	ng/L	0.4	10	0%	43	14%	7	14%
Endosulfan - Sulphate	P1ENDS	ng/L	0.1	10	60%	43	47%	7	0%
Endosulfan - I	P1END1	ng/L	0.1	10	0%	43	16%	7	0%
Endosulfan - II	P1END2	ng/L	0.4	10	40%	43	21%	7	0%
Heptachlorepoxide	P1HEPE	ng/L	0.1	10	50%	43	40%	7	14%
Heptachlor	P1HEPT	ng/L	0.1	10	20%	43	23%	7	0%
Mirex	P1MIRX	ng/L	0.5	10	0%	43	0%	7	14%
Oxychlordane	P1OCHL	ng/L	0.2	10	20%	43	2%	7	0%
OP-DDT	P1OPDT	ng/L	0.5	10	90%	43	74%	7	57%
PCB total	P1PCBT	ng/L	10	10	10%	43	67%	7	57%
PP-DDD	P1PPDD	ng/L	0.5	10	80%	43	79%	7	29%
PP-DDE	P1PPDE	ng/L	0.1	10	70%	43	88%	7	86%
PP-DDT	P1PPDT	ng/L	0.5	10	90%	43	77%	7	29%
Hexachlorobutadiene	X1HCBD	ng/L	0.1	10	10%	43	35%	7	14%
Hexachlorobenzene	X2HCB	ng/L	0.1	10	60%	43	49%	7	100%
Hexachloroethane	X2HCE	ng/L	0.1	10	0%	43	5%	7	14%
Octachlorostyrene	X2OCST	ng/L	0.1	10	20%	43	2%	7	0%
Pentachlorobenzene	X2PNCB	ng/L	0.1	10	40%	43	81%	7	100%
Trichlorotoluene 2-3-6	X2T236	ng/L	0.1	10	0%	43	7%	7	14%
Trichlorotoluene 2-4-5	X2T245	ng/L	0.1	10	0%	43	16%	7	0%
Trichlorotoluene 2-6-A	X2T26A	ng/L	0.1	10	0%	43	5%	7	29%
Trichlorobenzene 1-2-3	X2123	ng/L	0.1	10	0%	43	26%	7	0%
Tetrachlorobenzene 1-2-3-4	X21234	ng/L	0.1	10	0%	43	19%	7	43%
Tetrachlorobenzene 1-2-3-5	X21235	ng/L	0.1	10	0%	43	7%	7	43%
Trichlorobenzene 1-2-4	X2124	ng/L	0.2	10	10%	43	51%	7	71%
Tetrachlorobenzene 1-2-4-5	X21245	ng/L	0.1	10	0%	43	2%	7	43%
Trichlorobenzene 1-3-5	X2135	ng/L	0.2	10	60%	43	37%	7	29%

TABLE 4.1: SUMMARY OF FREQUENCY OF DETECTION BY OUTFALL TYPE (cont'd)

PARAMETER	MOE CODE	UNITS	MDL	STORM		CSO		MAIN WPCP BYPASS	
				# SAMPLES	% DETECT	# SAMPLES	% DETECT	# SAMPLES	% DETECT
POLYNUCLEAR AROMATIC HYDROCARBONS									
Acenaphthene	PNACNE	ng/L	0.5	9	67%	34	82%	7	71%
Acenaphthylene	PNACNY	ng/L	0.5	9	44%	42	43%	7	14%
Anthracene	PNANTH	ng/L	0.5	8	100%	43	93%	7	71%
Benzo (A) Anthracene	PNBAA	ng/L	0.5	7	100%	39	92%	6	67%
Benzo (A) Pyrene	PNBAP	ng/L	0.5	5	60%	33	94%	5	20%
Benzo (B) Fluoranthene	PNBBFA	ng/L	0.5	8	75%	39	95%	6	33%
Chrysene	PNCHRY	ng/L	0.5	7	100%	40	93%	6	67%
DiBenzo (AH) Anthracene	PNDAHA	ng/L	0.5	7	14%	38	37%	7	0%
Fluoranthene	PNFLAN	ng/L	0.5	9	89%	42	98%	7	100%
Fluorene	PNFLUO	ng/L	0.5	7	57%	43	84%	7	57%
Benzo (G,H,I) Perylene	PNGHIP	ng/L	0.5	10	80%	40	93%	7	14%
Indeno (1,2,3-CD) Pyrene	PNINP	ng/L	0.5	9	78%	42	88%	7	14%
Naphthalene	PNNAPH	ng/L	0.5	10	80%	44	100%	7	100%
Perylene	PNPERY	ng/L	0.5	8	38%	38	18%	7	0%
Phenanthrene	PNPHEN	ng/L	0.5	8	100%	43	95%	7	100%
Pyrene	PNPYR	ng/L	0.5	8	100%	43	100%	7	100%
1-Methylnaphthalene	PN1MNA	ng/L	0.5	9	89%	42	90%	7	57%
2-Methylnaphthalene	PN2MNA	ng/L	0.5	9	89%	41	90%	7	57%

MDL - Method Detection Limit
1. All metal concentrations are unfiltered totals.

TABLE 4.2: SUMMARY OF CONTAMINANT CONCENTRATIONS BY OUTFALL TYPE

Parameter	Units	MDL	PWQO	METRO BYLAW DSS	STORM SEWER OUTFALLS			CSO OUTFALLS			MAIN WPCP BYPASS		
					Mean	Confidence Interval LL	Confidence Interval UL	Mean	Confidence Interval LL	Confidence Interval UL	Mean	Confidence Interval LL	Confidence Interval UL
GENERAL CHEMISTRY													
Alkalinity	mg/L	0.02			97.50	78.87	120.53	134.00	122.37	146.74	249.00	209.89	295.40
Cyanide - avl. unfil. react.	mg/L	0.001			0.005	0.003	0.010	0.008	0.005	0.012	0.072	0.046	0.112
Chemical Oxygen Demand	mg/L	2			2250	1487	3405	1160	939	1433	524	260	1056
Ammonium - tot. filt. react.	mg/L	0.05			0.08	0.06	0.11	0.60'	N/A	N/A	22.40	14.94	33.58
Nitrates - tot. filt. react.	mg/L	0.05			1.96	0.79	4.85	0.70	0.45	1.08	0.085'	N/A	N/A
Nitrite - filt. react.	mg/L	0.005			0.140	0.069	0.284	0.160	0.100	0.250	0.017	0.009	0.033
Total kjeldahl Nitrogen	mg/L	0.05			4.11	3.48	4.85	5.68	4.84	12.22	52.00	41.53	65.11
Phenolics - unfilt. react.	ug/L	0.2	1.0		13.7	9.2	20.3	10.2	8.51	12.22	123.0	32.3	468.7
Total Phosphorus	mg/L	0.02	0.02 G		0.82	0.65	1.03	1.29	1.06	1.57	14.80	9.39	23.32
Total Suspended Solids	mg/L	0.3			238	158	358	322	255	407	476	239	950
Residue - total	mg/L	1		15	680	488	948	719	634	816	794	613	1028
Solvent Extractables	mg/L	0.5			4.1	2.1	8.0	4.8	3.4	6.8	31.8	16.3	61.9
BACTERIOLOGY													
Escherichia Coliform MF	CNT/100mL	4	100		409,000	151,900	1,101,200	1,563,600	998,872	2,447,605			
Fecal Coliform MF	CNT/100mL	4		200	528,000	195,000	1,429,500	1,902,358	1,217,815	2,971,689			
Fecal Streptococcus MF	CNT/100mL	4			122,000	58,000	256,500	231,000	168,592	316,509			
Pseudomonas Aeruginosa MF	CNT/100mL	2			988	569	1,717	22,900	13,802	37,997			
HEAVY METALS													
Silver	mg/L	0.001	0.0001		0.002	0.0009	0.004	0.004	0.003	0.006	0.110	0.039	0.311
Aluminum	mg/L	0.005	0.075 G		1.40	1.06	1.85	4.08	3.17	5.25	4.48	1.89	10.60
Barium	mg/L	0.005			0.041	0.034	0.049	0.098	0.088	0.109	0.320	0.152	0.672
Beryllium	mg/L	0.0001			.00013	.00007	0.00024	.00017	.00014	0.00020	0.00014	0.00006	0.00035
Cadmium	mg/L	0.0001	0.0002	0.001	.00094	.00061	0.00146	.001'	N/A	N/A	0.011	0.005	0.028
Chromium	mg/L	0.001	0.1	0.2	0.007	0.005	0.011	0.021	0.016	0.028	0.300	0.159	0.567
Copper	mg/L	0.0001	0.005	0.01	0.045	0.039	0.052	0.092	0.077	0.110	0.590	0.301	1.157
Iron	mg/L	0.01	0.3		2.83	2.34	3.42	8.46	7.16	9.99	37.50	16.39	85.82
Mercury	ug/L	0.02	0.2	1.0	0.04	0.03	0.05	0.10	0.08	0.12	0.64	0.16	2.61
Manganese	mg/L	0.001			0.160	0.130	0.200	0.350	0.300	0.408	0.170	0.094	0.308
Nickel	mg/L	0.001	0.025	0.05	0.010	0.007	0.015	0.015	0.013	0.018	0.050'	N/A	N/A
Lead	mg/L	0.005	0.005	0.05	0.057	0.046	0.070	0.110	0.094	0.128	0.130	0.064	0.265
Zinc	mg/L	0.001	0.03	0.05	0.150	0.130	0.173	0.250	0.215	0.290	0.840	0.405	1.743
ORGANOCHLORINE PESTICIDES/CHLOROBENZENES/PCBs													
Aldrin	ng/L	0.1	1.0		N/A	N/A	N/A	1.5'	N/A	N/A	0.24'	N/A	N/A
Alpha-bhc	ng/L	0.1			1.84	1.32	2.56	1.88	1.24	2.84	1.47	0.45	4.82
Gamma-bhc (Lindane)	ng/L	0.1	10.0		1.03	0.60	1.77	2.77	2.03	3.79	5.10	1.49	17.49
Chlordane - alpha	ng/L	0.2	60.0		2.45	1.26	4.75	3.20	2.06	4.97	4.75	0.85	26.57
Chlordane - gamma	ng/L	0.2	60.0		2.69	1.33	5.44	3.18	1.85	5.45	4.09	1.03	16.26
Dieldrin	ng/L	0.2	1.0		2.39	0.86	6.62	3.17	2.22	4.53	0.70	0.28	1.72
DMDT - Methoxychlor	ng/L	0.4			1.78	0.82	3.87	2.98	2.08	4.27	N/A	N/A	N/A
Endosulfan - Sulphate	ng/L	0.1			0.62	0.39	0.99	0.62	0.48	0.80	N/A	N/A	N/A

TABLE 4.2: SUMMARY OF CONTAMINANT CONCENTRATIONS BY OUTFALL TYPE

Parameter	Units	MDL	PWQO	METRO BYLAW DSS	STORM SEWER OUTFALLS			CSO OUTFALLS			MAIN WPCP BYPASS		
					Mean	Confidence Interval		Mean	Confidence Interval		Mean	Confidence Interval	
						LL	UL		LL	UL		LL	UL
Endosulfan - II	ng/L	0.4			0.41	0.29	0.58	0.49	0.29	0.84	N/A	N/A	N/A
Heptachlorepoxide	ng/L	0.1	1.0		0.14	0.09	0.22	0.16	0.11	0.23	N/A	N/A	N/A
Heptachlor	ng/L	0.1	1.0		0.58#	N/A	N/A	0.15	0.09	0.26	N/A	N/A	N/A
OP-DDT	ng/L	0.5			2.12	1.23	3.65	2.15	1.55	2.99	2.42	0.82	7.11
PCB total	ng/L	10	1.0		N/A	N/A	N/A	65	42	99	74	20	268
PP-DDD	ng/L	0.5			0.97	0.60	1.56	4.35	2.84	6.67	0.64#	N/A	N/A
PP-DDE	ng/L	0.1			1.23	0.65	2.32	2.25	1.53	3.32	8.3	1.64	42.07
PP-DDT	ng/L	0.5			5.31	2.83	9.96	8.19#	N/A	N/A	1.26#	N/A	N/A
Hexachlorobutadiene	ng/L	0.1			N/A	N/A	N/A	0.19	0.12	0.30	N/A	N/A	N/A
Hexachlorobenzene	ng/L	0.1	6.5		0.21	0.12	0.36	0.30	0.19	0.48	1.96	0.77	5.01
Pentachlorobenzene	ng/L	0.1	30.0		0.60	0.37	0.96	0.99	0.67	1.47	2.73	1.35	5.53
Trichlorotoluene 2-6-A	ng/L	0.1			N/A	N/A	N/A	N/A	N/A	N/A	0.09#	N/A	N/A
Trichlorobenzene 1-2-3	ng/L	0.1	900.0		N/A	N/A	N/A	0.74	0.55	1.00	N/A	N/A	N/A
Tetrachlorobenzene 1-2-3-4	ng/L	0.1	100.0		N/A	N/A	N/A	0.58	0.43	0.78	0.99#	N/A	N/A
Tetrachlorobenzene 1-2-3-5	ng/L	0.1	100.0		N/A	N/A	N/A	N/A	N/A	N/A	1.15	0.16	8.08
Trichlorobenzene 1-2-4	ng/L	0.2	500.0		N/A	N/A	N/A	2.22	1.71	2.88	14.60	5.42	39.29
Tetrachlorobenzene 1-2-4-5	ng/L	0.1	150.0		N/A	N/A	N/A	N/A	N/A	N/A	2.02	0.99	4.13
Trichlorobenzene 1-3-5	ng/L	0.2	650.0		1.71	1.16	2.53	2.90	2.15	3.92	0.46#	N/A	N/A
POLYNUCLEAR AROMATIC HYDROCARBONS													
Acenaphthene	ng/L	0.5			19	7	52	49	33	75	19#	N/A	N/A
Acenaphthylene	ng/L	0.5			12	5.2	30	24	17	33	N/A	N/A	N/A
Anthracene	ng/L	0.5			94	37	236	156	94	259	20#	N/A	N/A
Benzo (A) Anthracene	ng/L	0.5			59	30	117	148#	N/A	N/A	21#	N/A	N/A
Benzo (A) Pyrene	ng/L	0.5			48	22	104	173#	N/A	N/A	N/A	N/A	N/A
Benzo (B) Fluoranthene	ng/L	0.5			119	57	249	466	315	689	67#	N/A	N/A
Chrysene	ng/L	0.5			80	45	143	236	170	329	41#	N/A	N/A
DiBenzo (AH) Anthracene	ng/L	0.5			N/A	N/A	N/A	17.7#	N/A	N/A	N/A	N/A	N/A
Fluoranthene	ng/L	0.5			500	145	1728	652	458	928	181	64	512
Fluorene	ng/L	0.5			16#	-	-	57.5#	N/A	N/A	17#	N/A	N/A
Benzo (G,H,I) Perylene	ng/L	0.5			194	60	623	179	127	252	N/A	N/A	N/A
Indeno (1,2,3-CD) Pyrene	ng/L	0.5			110	38	318	199	141	281	N/A	N/A	N/A
Naphthalene	ng/L	0.5			237	67	842	501	319	787	1090	279	4255
Perylene	ng/L	0.5			21	9	49	N/A	N/A	N/A	N/A	N/A	N/A
Phenanthrene	ng/L	0.5			186	96	361	454	323	638	167	64	435
Pyrene	ng/L	0.5			175	96	319	423	296	604	178	68	468
1-Methylnaphthalene	ng/L	0.5			58	25	136	181	127	258	93	39	218
2-Methylnaphthalene	ng/L	0.5			112	39	325	261	182	375	128	50	327

Note: All heavy metals are unfiltered totals.
MDL - Method Detection Limit.
PWQO - Provincial Water Quality Objective: G - Provincial Water Quality Guideline. Metro Bylaw Targets based on Metropolitan Toronto Sewer Use Bylaw No. 153-89 - Discharges to Storm Sewers
LL - Lower Limit for 95% confidence interval.
UL - Upper Limit for 95% confidence interval.
N/A - not applicable, either less than 20% detection and/or less than 3 detected values.
- Half Detection Limit assigned to detection limit values.

TABLE 4.3: EXCEEDANCES OF APPLICABLE PWQO/G OR METRO SEWER USE BYLAW TARGET CONCENTRATIONS BY DISCHARGE TYPE

Parameter	Units	PWQO/G	METRO BYLAW TARGET	STORM SEWER OUTFALLS	CSO OUTFALLS	MAIN WPCP BYPASS
GENERAL CHEMISTRY						
Phenolics - unfilt. react.	ug/L	1.0				
Total Phosphorus	mg/L	0.02 G				
Total Suspended Solids	mg/L		15			
BACTERIOLOGY						
Escherichia Coliform	CNT/100 mL	100				NA
Fecal Coliform MF	CNT/100 mL		200			NA
HEAVY METALS						
Aluminum	mg/L	0.075 G				
Cadmium	mg/L	0.0002	0.001			
Chromium	mg/L	0.1	0.2			
Copper	mg/L	0.005	0.01			
Iron	mg/L	0.3				
Mercury	ug/L	0.2	1.0			
Nickel	mg/L	0.025	0.05			
Lead	mg/L	0.005	0.05			
Silver	mg/L	0.0001				
Zinc	mg/L	0.03	0.05			
ORGANOCHLORINE PESTICIDES/CHLOROBENZENES/PCBs						
Aldrin	ng/L	1.0				
Gamma-bhc (Lindane)	ng/L	10.0				
Chlordane - alpha	ng/L	60.0				
Chlordane - gamma	ng/L	60.0				
Dieldrin	ng/L	1.0				
Heptachlorepoxide	ng/L	1.0				
Heptachlor	ng/L	1.0				
PCB Total	ng/L	1.0				
Hexachlorobenzene	ng/L	6.5				
Pentachlorobenzene	ng/L	30.0				
Trichlorobenzene 1-2-3	ng/L	900.0				
Tetrachlorobenzene 1-2-3-4	ng/L	100.0				
Tetrachlorobenzene 1-2-3-5	ng/L	100.0				
Trichlorobenzene 1-2-4	ng/L	500.0				
Tetrachlorobenzene 1-2-4-5	ng/L	150.0				
Trichlorobenzene 1-3-5	ng/L	650.0				

Note - the shaded boxes indicate exceedance of applicable PWQO/G or Metro Bylaw Target
PWQO/G - Provincial Water Quality Objective/Guideline.
Metro Bylaw Targets based on Metropolitan Toronto Sewer Use Bylaw No.153-89 - Discharges to Storm Sewers.
NA - not available

TABLE 4.4: COMPARISON OF STORMWATER EMC DATA

Parameter	Units	STUDY			
		Phase II	Phase I	NURP[1]	UGLCC
GENERAL CHEMISTRY					
Alkalinity (as $CaCO_3$)	mg/L	97.5	83.6	-	-
Chemical Oxygen Demand	mg/L	2250	740	57-73	-
Nitrates	mg/L	1.96	4.89	-	-
Nitrite	mg/L	0.14	0.05	-	-
Phenolics	µg/L	13.7	16.3	-	-
Total Kjeldahl Nitrogen	mg/L	4.11	2.42	1.18-1.90	-
Total Phosphorous	mg/L	0.82	0.49	0.2-0.38	0.16-0.37
Total Suspended Solids	mg/L	238	128	67-101	-
BACTERIOLOGY					
Escherichia Coliform	CNT/100mL	409,000	177,000	-	-
Fecal Coliforms	CNT/100mL	528,000	403,000	21,000	-
HEAVY METALS					
Chromium	mg/L	0.001	0.005	0.014	0.006
Copper	mg/L	0.045	0.16	0.10	0.009-0.087
Iron	mg/L	2.83	4.42	-	3.0-11.4
Lead	mg/L	0.057	0.046	0.006-0.46	0.06-0.45
Mercury	ug/L	0.04	.050	0.6-1.2	0.018-0.18
Nickel	mg/L	0.010	.012	0.001-0.18	0.003-0.039
Zinc	mg/L	0.150	0.190	0.01-2.40	0.16-0.48
ORGANOCHLORINE PESTICIDES/CHLOROBENZENES/PCBs					
Alpha-bhc	ng/L	1.84	1.88	2.7	-
Gamma-bhc (Lindane)	ng/L	1.03	1.14	7.01	-
Dieldrin	ng/L	2.39	0.80	-	-
Hexachlorobenzene	ng/L	0.21	0.32	-	-
Tetrachlorobenzene 1-2-3-5	ng/L	-	3.25	-	-
POLYNUCLEAR AROMATIC HYDROCARBONS					
Anthracene	ng/L	94	51	-	-
Benzo (A) Anthracene	ng/L	59	249	-	-
Benzo (A) Pyrene	ng/L	48	320	-	-
Benzo (B) Fluoranthene	ng/L	119	553	1,000-5,000	-
Chrysene	ng/L	80	333	-	-
Indeno (1,2,3-CD) Pyrene	ng/L	110	274	4,000	-
Phenanthrene	ng/L	186	555	-	-

Phase I - Metropolitan Toronto Wet Weather Outfall Study, Phase I (Paul Theil Associates Limited, 1992).
Phase II - Metropolitan Toronto Wet Weather Outfall Study, Phase II (Aquafor Engineering Limited, 1993).
NURP - Nationwide Urban Runoff Program (U.S. EPA, 1983).
TAWMS - Toronto Area Watershed Management Strategy Study (W.M. Wong, 1986).
UGLCC - Upper Great Lakes Connecting Channels Area Study (Marsalek and Ng, 1987).

TABLE 4.5: COMPARISON OF COMBINED SEWER OVERFLOW (CSO) EMC DATA

Parameter	Units	STUDY				
		Phase II	Phase I	NURP[1]	TAWMS	UGLCC
GENERAL CHEMISTRY						
Alkalinity (as $CaCO_3$)	mg/L	134	112			
Chemical Oxygen Demand	mg/L	1160	1,050	132	-	-
Nitrates	mg/L	0.70	0.88	1.0	-	-
Nitrite	mg/L	0.16	0.150	0.1	-	-
Phenolics	µg/L	10.2	19.2			
Total Kjeldahl Nitrogen	mg/L	5.68	8.16	6.5	-	-
Total Phosphorous	mg/L	1.29	1.75	2.4	1.96	0.4-3.4
Total Suspended Solids	mg/L	322	801	184	196	-
BACTERIOLOGY						
Escherichia Coliform	CNT/100mL	1,563,600	445,000			
Fecal Coliforms	CNT/100mL	1,902,400	1,892,700	1,000,000	1,650,000	-
HEAVY METALS						
Chromium	mg/L	0.021	0.028	0.09	-	-
Copper	mg/L	0.092	0.110	0.102	0.119	0.10-0.14
Iron	mg/L	8.46				
Lead	mg/L	0.110	0.120	0.346	0.182	0.05-0.29
Mercury	ug/L	0.10				
Nickel	mg/L	0.015				
Zinc	mg/L	0.250	0.280	0.348	0.300	0.24-0.34
ORGANOCHLORINE PESTICIDES/CHLOROBENZENES/PCBs						
Alpha-bhc	ng/L	1.88	2.11			
Gamma-bhc (Lindane)	ng/L	2.77	3.87	-	-	-
Dieldrin	ng/L	3.17	3.41	-	-	-
Hexachlorobenzene	ng/L	0.30	0.52	-	-	-
Tetrachlorobenzene 1-2-3-5	ng/L	-	2.20	-	-	-
POLYNUCLEAR AROMATIC HYDROCARBONS						
Anthracene	ng/L	156	196	-	-	-
Benzo (A) Anthracene	ng/L	148	226	-	-	-
Benzo (A) Pyrene	ng/L	173	264	-	-	-
Benzo (B) Fluoranthene	ng/L	466	557			
Chrysene	ng/L	236	262	-	-	-
Indeno (1,2,3-CD) Pyrene	ng/L	199	322			
Phenanthrene	ng/L	454	542	-	-	-

Phase I - Metropolitan Toronto Wet Weather Outfall Study, Phase I (Paul Theil Associates Limited, 1992).
Phase II - Metropolitan Toronto Wet Weather Outfall Study, Phase II (Aquafor Engineering Limited, 1993).
NURP - Nationwide Urban Runoff Program (U.S. EPA, 1983).
TAWMS - Toronto Area Watershed Management Strategy Study (W.M. Wong, 1986).
UGLCC - Upper Great Lakes Connecting Channels Area Study (Marsalek and Ng, 1987).

5.0 SEASONAL CONTAMINANT LOADINGS

Mean contaminant mass loadings for the seasonal period of 01 May through 31 October are summarized in this section for those parameters in which the detection frequency exceeded 20 percent for at least one of the three outfall types (i.e., Storm, CSO, Bypass). The loadings were estimated using contaminant concentrations obtained in this study and predictions of flow volumes using computer simulation. A typical rainfall distribution, selected as 01 May through 31 October 1980, was used to generate estimates of flow discharges for each outfall.

Contaminant loadings are presented by outfall type and geographic region. In general, it was found that the relative contribution of contaminant mass loadings by either outfall type or geographic region is significantly influenced by flow volume. Therefore, consistent with the seasonal flow volumes summarized in Section 3.2.3, loadings associated with CSO outfalls and to the Toronto Inner Harbour area are the greatest for the majority of parameters.

For illustrative purposes, contaminant loadings from the various outfall types for representative parameters of each parameter grouping are presented in Figure 5.1 through Figure 5.4. A complete summary of loadings by outfall type is presented in Table 5.1. Consistent with the estimates of flow volumes discharged (Section 3.2.3), contaminant loadings from CSO outfalls are typically an order of magnitude larger than those from Storm outfalls. While CSO flow volumes were estimated to exceed bypassed primary effluent at the Metro Main WPCP by a factor of 12 (see Section 3.2.3), contaminant mass loadings from this source are either similar or exceed loadings from CSO outfalls for:

- ammonium;
- cyanide;
- total phosphorus;
- phenolics;

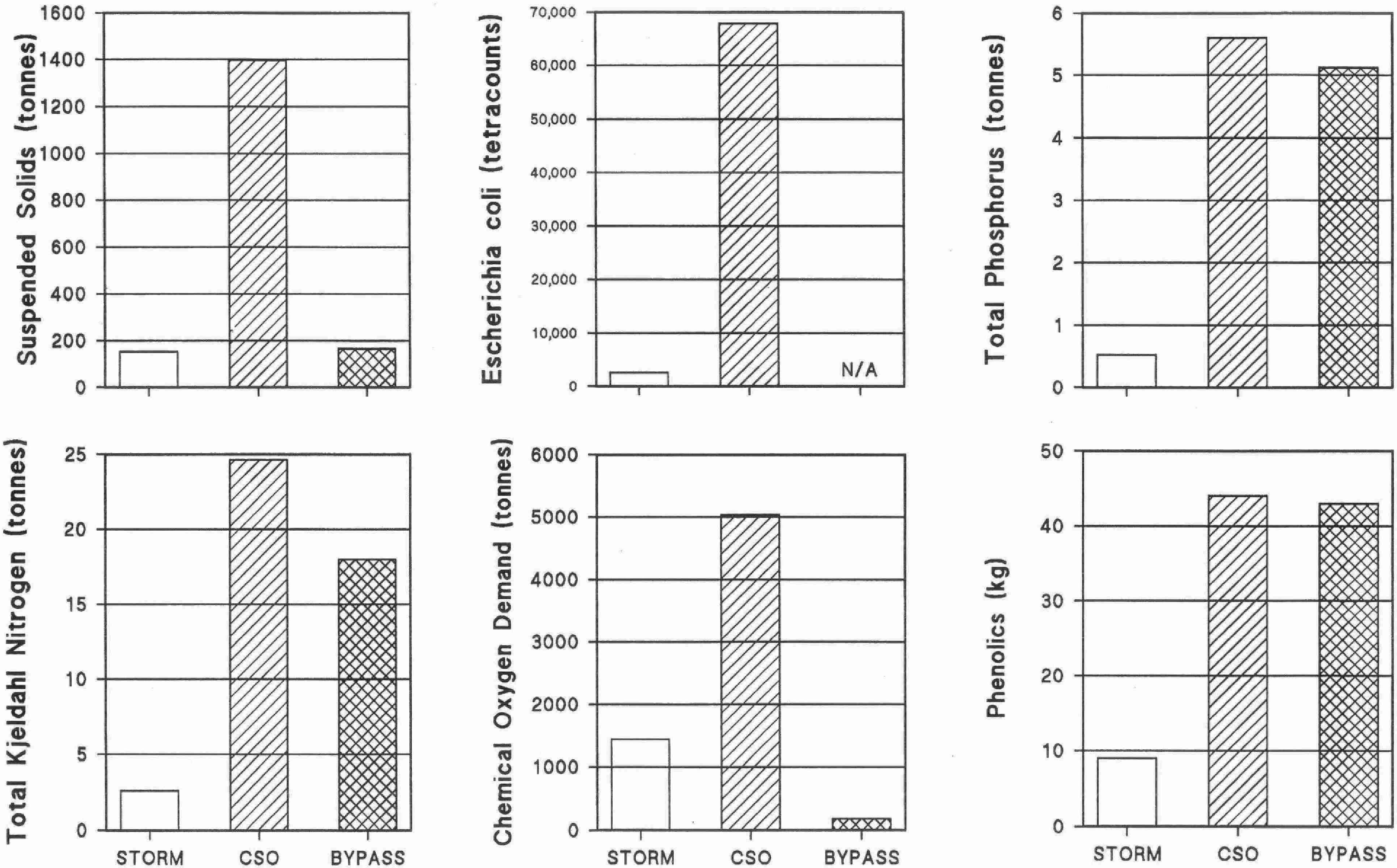


FIGURE 5.1 MEAN SEASONAL MASS LOADINGS BY OUTFALL TYPE - CONVENTIONAL PARAMETERS

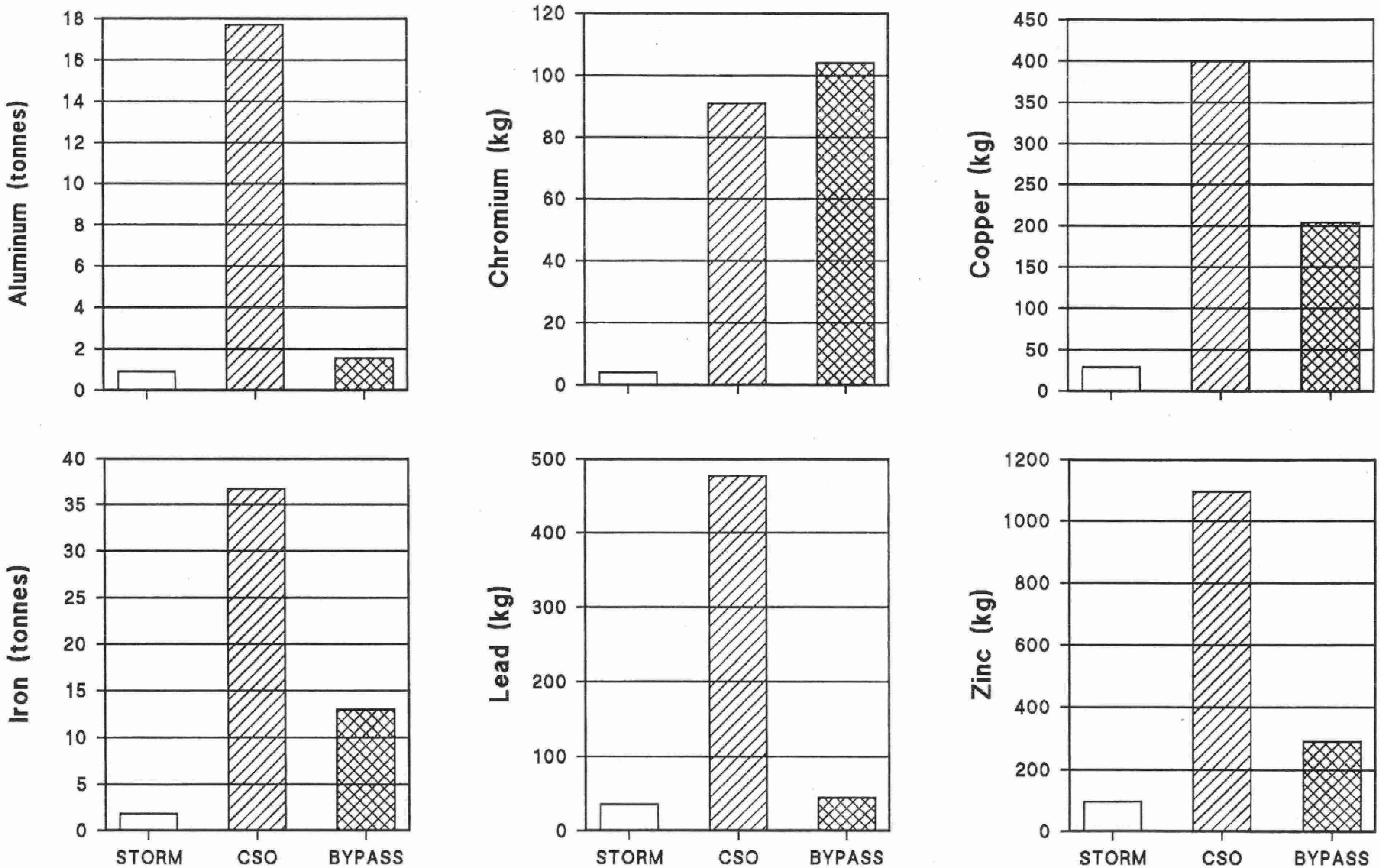


FIGURE 5.2 MEAN SEASONAL MASS LOADINGS BY OUTFALL TYPE - HEAVY METALS

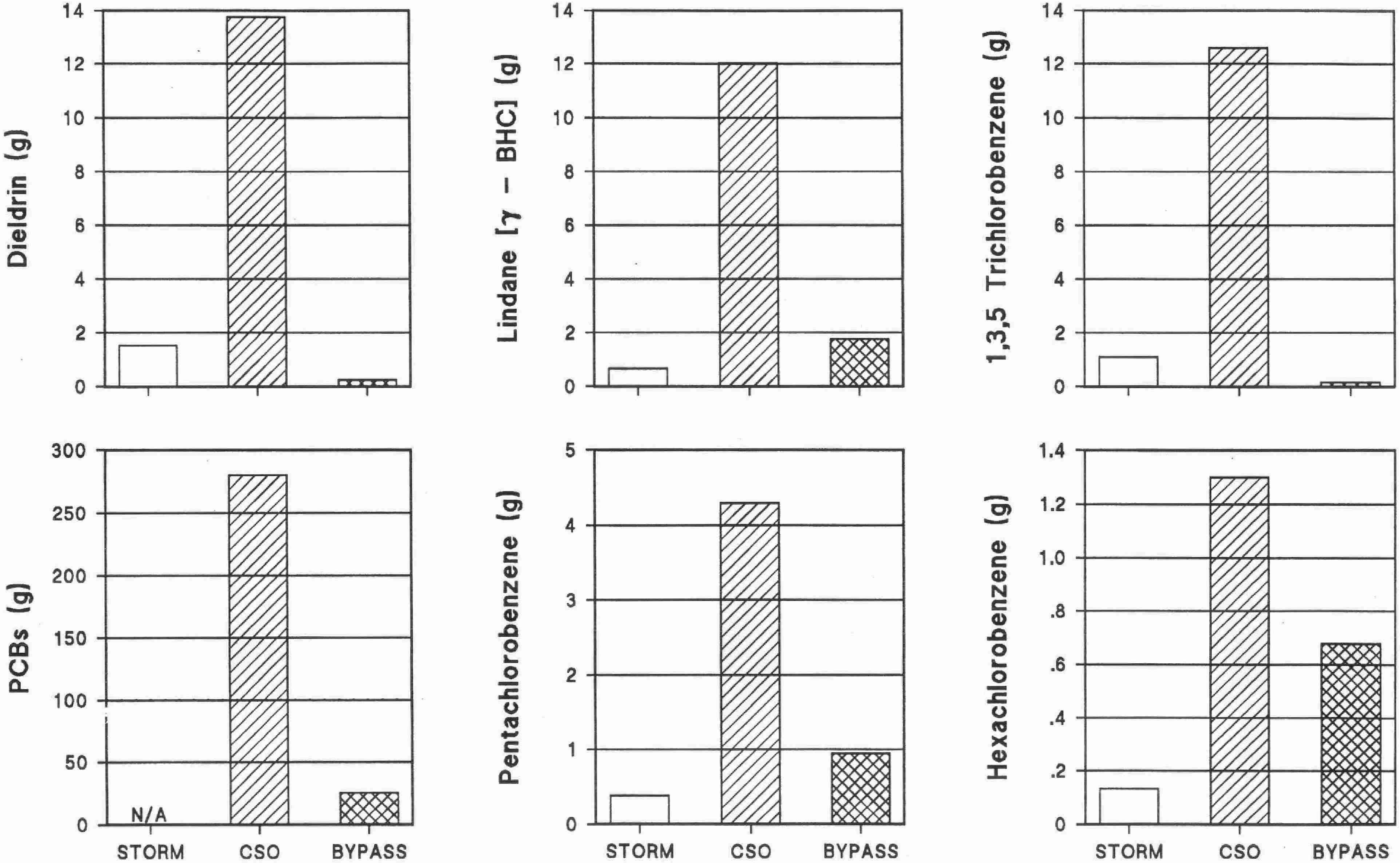


FIGURE 5.3 MEAN SEASONAL MASS LOADINGS BY OUTFALL TYPE - ORGANOCHLORINE/CHLOROBENZENE PESTICIDES AND PCBs

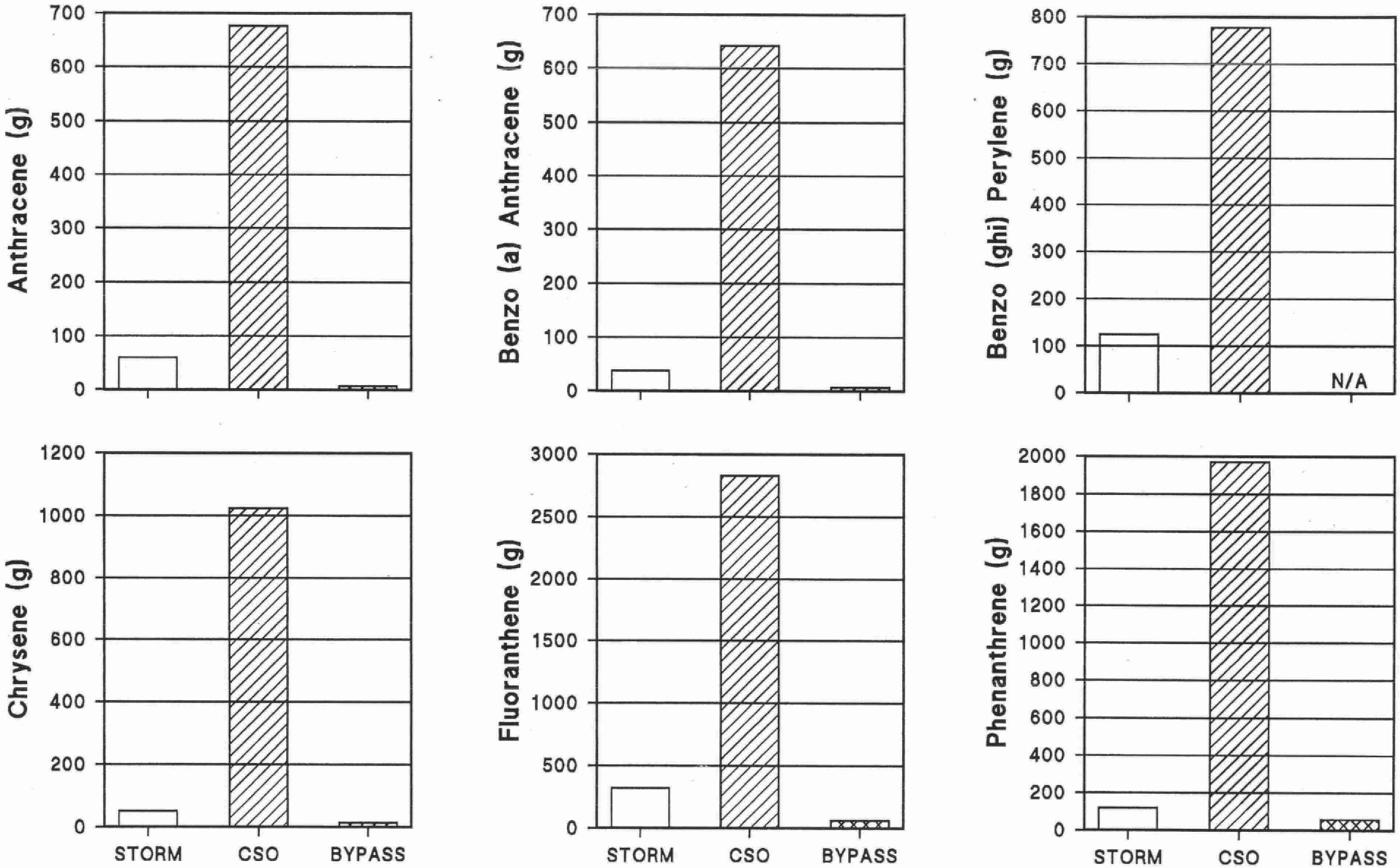


FIGURE 5.4 MEAN SEASONAL MASS LOADINGS BY OUTFALL TYPE - POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

- cadmium;
- chromium; and
- silver.

This is attributed to higher observed contaminant concentrations in bypasses of primary effluent at the Main WPCP as a result of the sanitary sewage component.

A detailed summary of seasonal mass loadings by both outfall type and geographic region is provided in Appendix B (Table B.1 and Table B.2). For illustrative purposes, presented in Figure 5.5 through Figure 5.8 are contaminant mass loadings, by geographic region, for representative parameters of each parameter grouping. The regions considered are as follows:

- Western Beaches;
- Toronto Inner Harbour;
- Ashbridges Bay; and
- Eastern Beaches.

As with contaminant mass loadings by outfall type, the relative contribution is to a large degree a function of flow volume. In most cases, loadings are highest to the Inner Harbour followed by the Western Beaches, Ashbridges Bay, and the Eastern Beaches. Loadings to the Eastern Beaches are typically an order of magnitude lower than loadings to the other regions. For most parameters, in the order of 40 percent to 60 percent of the loadings are discharged to the Toronto Inner Harbour. Several notable exceptions are as follows:

- cyanide;
- ammonium
- total kjeldahl nitrogen;
- total phosphorus;
- phenolics;

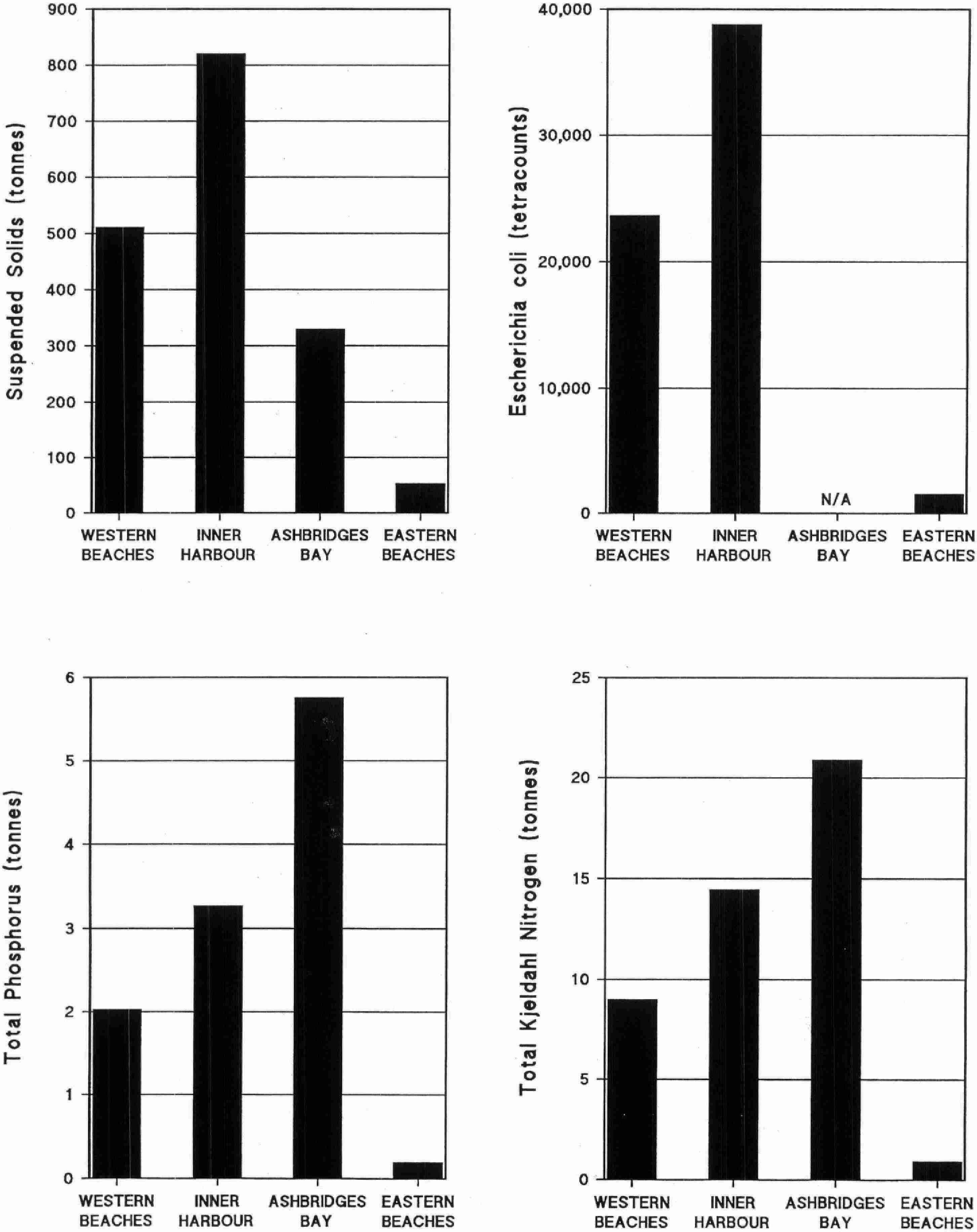


FIGURE 5.5 MEAN SEASONAL MASS LOADINGS BY REGION - CONVENTIONAL PARAMETERS

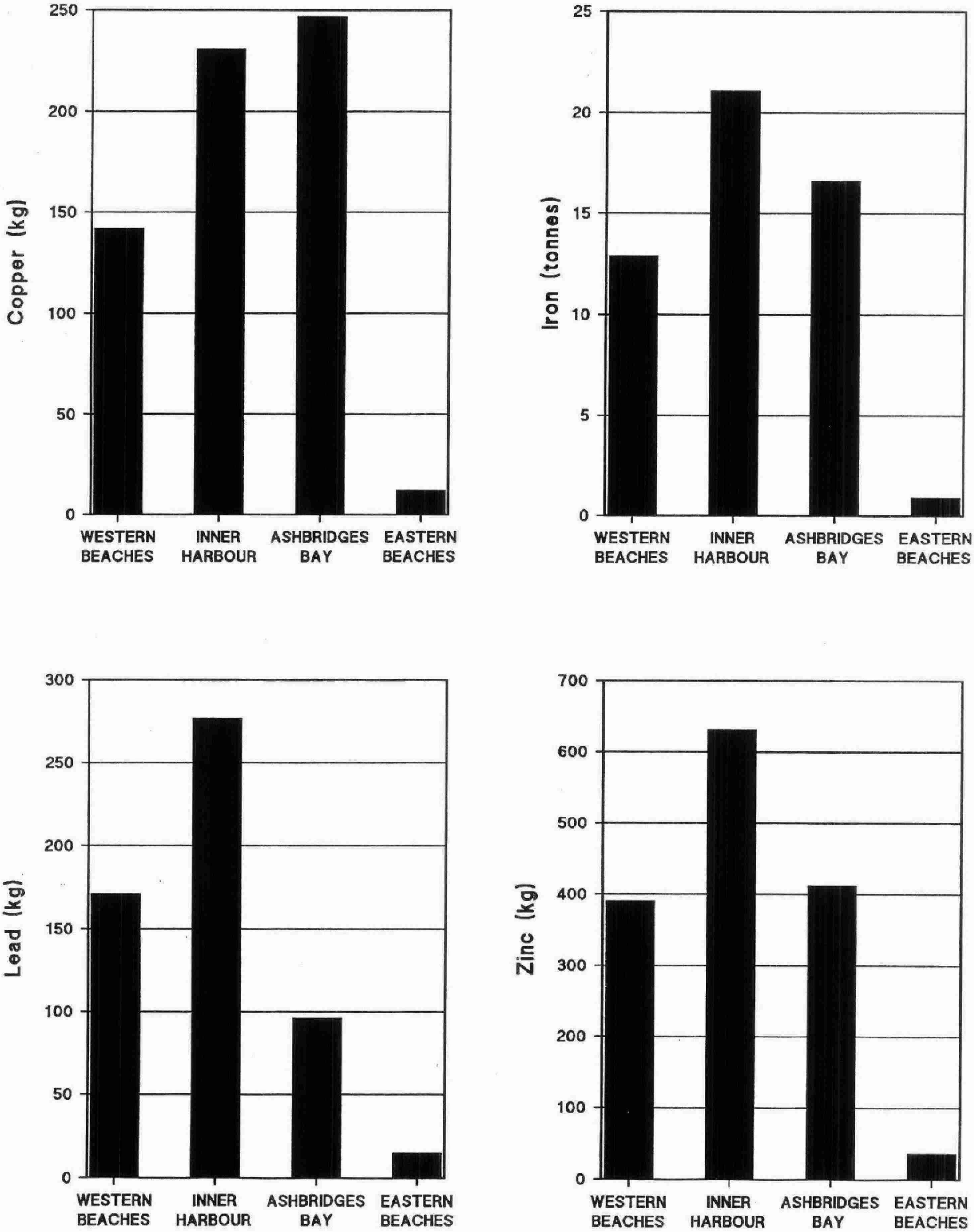


FIGURE 5.6 MEAN SEASONAL MASS LOADINGS BY REGION - HEAVY METALS

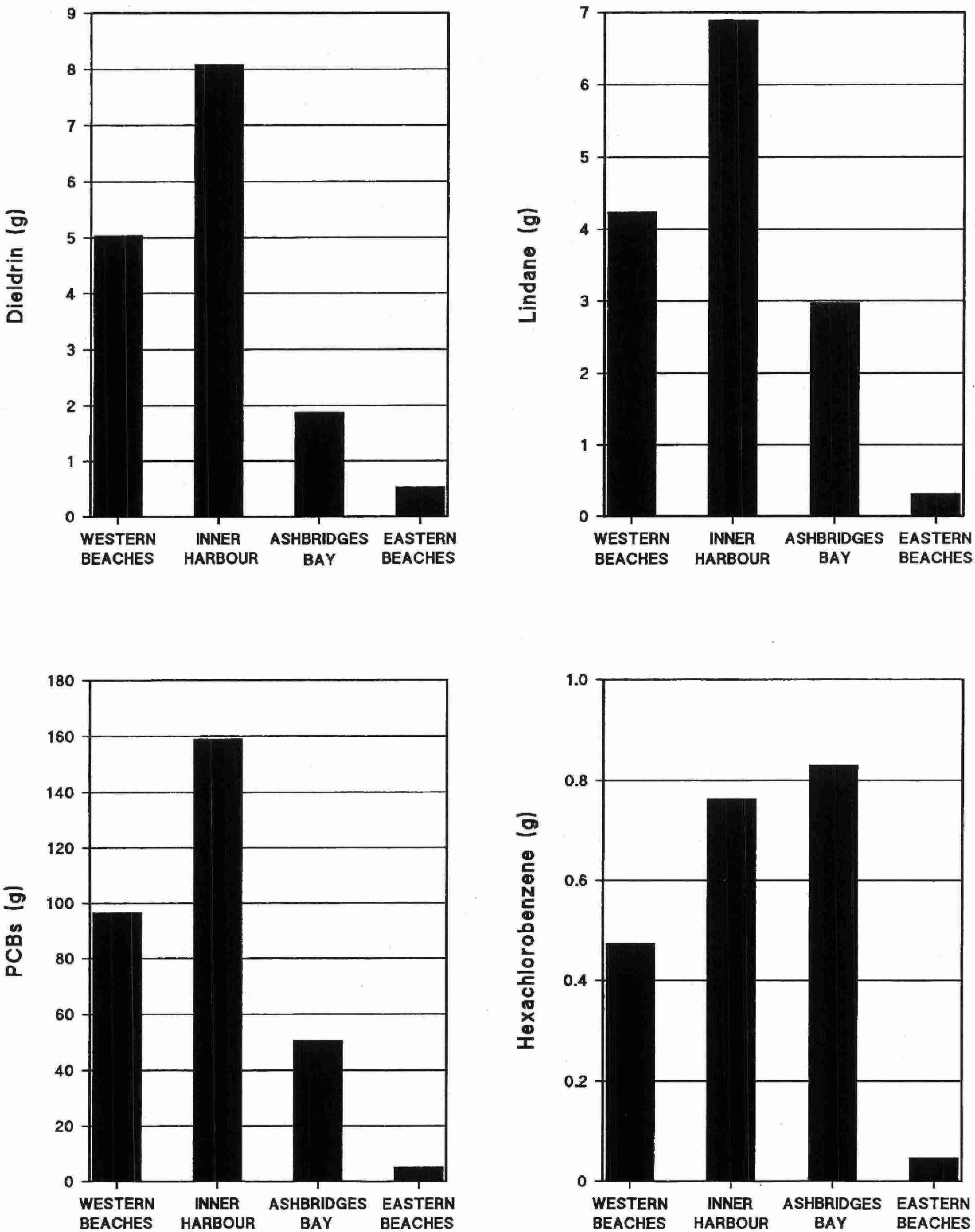


FIGURE 5.7 MEAN SEASONAL MASS LOADINGS BY REGION - ORGANOCHLORINE/CHLOROBENZENE PESTICIDES AND PCBs

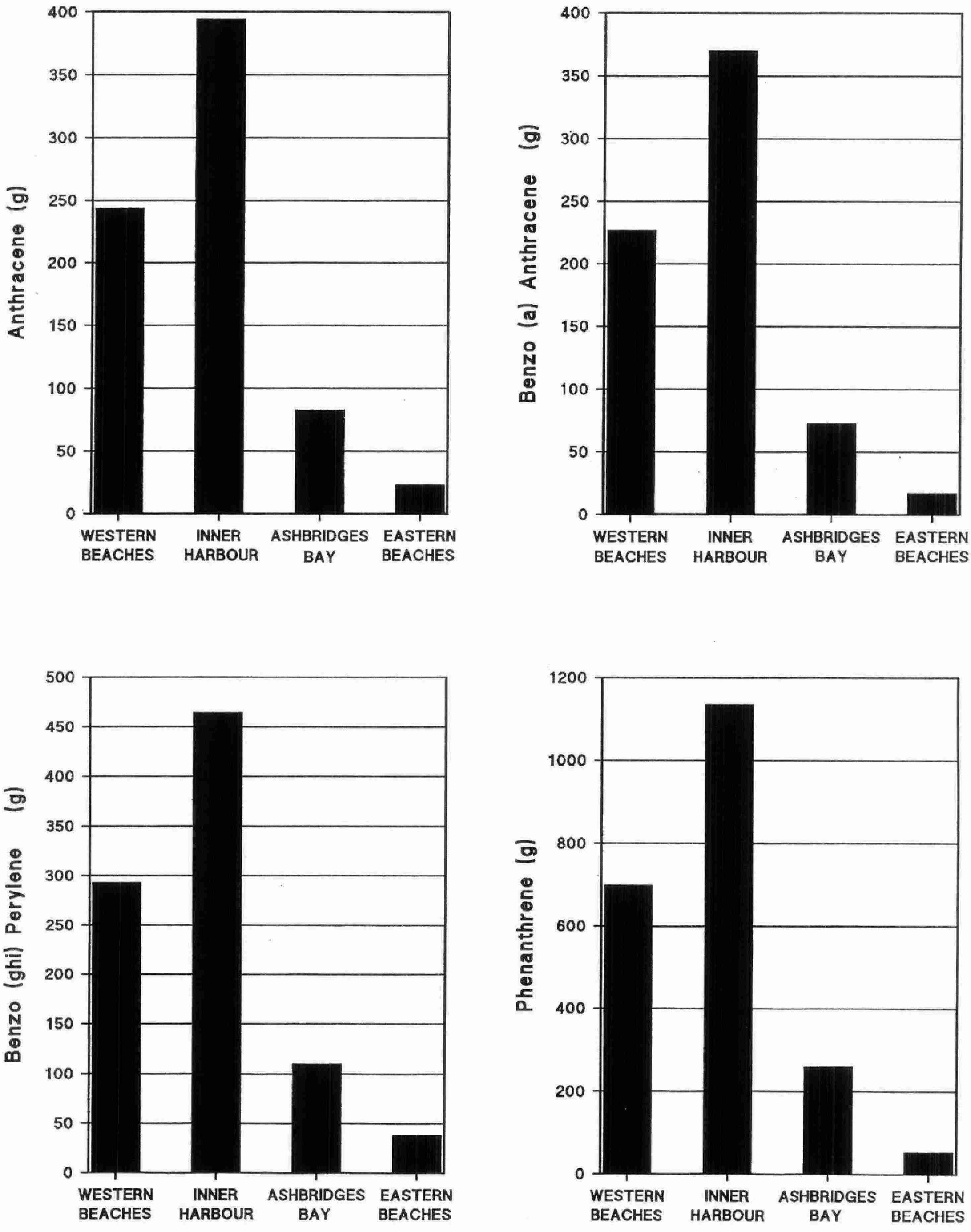


FIGURE 5.8 MEAN SEASONAL MASS LOADINGS BY REGION - POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

- silver;
- cadmium;
- chromium;
- copper; and
- mercury.

For these parameters, loadings to the Ashbridges Bay region are either similar or greater than those to the Toronto Inner Harbour due to bypasses of primary effluent at the Main WPCP.

It should be emphasized that the picture portrayed here is based on sewer discharge configurations which existed in 1990. The distribution of contaminant mass loadings by both outfall type and geographic region is continuing to change as a result of ongoing improvements to the City of Toronto sewerage system. For example, completion of the Phase II Eastern Beaches Detention Tank will result in a reduction of loadings to the Eastern Beaches area, and an overall reduction of loadings from both Storm and CSO outfalls to the waterfront.

Furthermore, the information presented in this section represents seasonal loadings for the period 01 May through 31 October. The Phase I Metropolitan Toronto Waterfront Wet Weather Outfall Study (Paul Theil Associates Limited *et al.*, 1992) included an analysis of historical precipitation data and flow data from area watercourses. This showed that while precipitation was equally distributed over the May to October (summer/fall) and November to April (winter/spring) periods, winter/spring flow contributions from area watercourses represented approximately two thirds the annual total. This would suggest that in some areas, stormwater contaminant mass contributions during the winter/spring period could double those estimated for the summer/fall period. A parallel study (Aquafor Beech Limited, 1994) is being conducted to address this issue, by characterizing seasonal contaminant concentrations, flow volumes, and mass loadings at representative catchments within the City of Toronto.

TABLE 5.1: SUMMARY OF CONTAMINANT LOADINGS

Parameter	Units	Loadings by Outfall Type			TOTAL LOADINGS
		Storm	CSO	Main ByPass	
FLOW	m^3	640,264	4,338,640	346,000	5,324,904
GENERAL CHEMISTRY					
Chemical Oxygen Demand	kg	1,440,594	5,032,832	181,304	6,654,720
Ammonium - tot. filt. react.	kg	51	2,603	7,750	10,404
Nitrates - tot. filt. react.	kg	1,255	3,037	29	4,321
Nitrite - filt. react.	kg	90	694	6	790
Total kjeldahl Nitrogen	kg	2,631	24,643	17,992	45,267
Phenolics - unfilt. react.	kg	9	44	43	96
Total Phosphorus	kg	525	5,597	5,121	11,243
Total Suspended Solids	kg	152,383	1,397,042	164,696	1,714,121
Residue - total	kg	435,380	3,119,482	274,724	3,829,586
Solvent Extractables	kg	2,625	20,782	11,003	34,410
Cyanide - avl. unfil. react.	kg	3	35	25	63
BACTERIOLOGY					
Escherichia Coliform MF	Tcts	2,619	67,839		
Fecal Coliform MF	Tcts	3,381	82,536		
Fecal Streptococcus MF	Tcts	781	10,022		
Pseudomonas Aeruginosa MF	Tcts	6	994		
HEAVY METALS					
Silver	kg	1	17	38	57
Aluminum	kg	896	17,702	1,550	20,148
Barium	kg	26	425	111	562
Berylium	kg	0.08	0.74	0.05	0.87
Cadmium	kg	1	4	4	9
Chromium	kg	4	91	104	199
Copper	kg	29	399	204	632
Iron	kg	1,812	36,705	12,975	51,492
Mercury	g	26	434	221	681
Manganese	kg	102	1,519	59	1,680
Nickel	kg	6	65	17	89
Lead	kg	36	477	45	559
Zinc	kg	96	1,095	291	1,471
ORGANOCHLORINE PESTICIDES/CHLOROBENZENES/PCBs					
Aldrin	mg	N/A	6,508	83	6,591
Alpha-bhc	mg	1,178	8,157	509	9,843
Gamma-bhc (Lindane)	mg	659	12,018	1,765	14,442
Chlordane - alpha	mg	1,569	13,884	1,644	17,096
Chlordane - gamma	mg	1,722	13,797	1,415	16,934
Dieldrin	mg	1,530	13,753	242	15,526
DMDT - Methoxychlor	mg	1,140	12,929	N/A	14,069
Endosulfan - Sulphate	mg	397	2,690	N/A	3,087
Endosulfan - II	mg	263	2,126	N/A	2,389
Heptachlorepoxide	mg	90	694	N/A	784
Heptachlor	mg	371	651	N/A	1,021
OP-DDT	mg	1,357	9,328	837	11,523

TABLE 5.1: SUMMARY OF CONTAMINANT LOADINGS

Parameter	Units	Loadings by Outfall Type			TOTAL LOADINGS
		Storm	CSO	Main ByPass	
PCB total	mg	N/A	280,276	25,604	305,880
PP-DDD	mg	621	18,873	221	19,716
PP-DDE	mg	788	9,762	2,872	13,421
PP-DDT	mg	3,400	35,533	436	39,369
Hexachlorobutadiene	mg	N/A	824	N/A	824
Hexachlorobenzene	mg	134	1,302	678	2,114
Pentachlorobenzene	mg	384	4,295	945	5,624
Trichlorotoluene 2-6-A	mg	N/A	N/A	31	31
Trichlorobenzene 1-2-3	mg	N/A	3,211	N/A	3,211
Tetrachlorobenzene 1-2-3-4	mg	N/A	2,516	343	2,8599
Tetrachlorobenzene 1-2-3-5	mg	N/A	N/A	398	398
Trichlorobenzene 1-2-4	mg	N/A	9,632	5,052	14,684
Tetrachlorobenzene 1-2-4-5	mg	N/A	N/A	699	699
Trichlorobenzene 1-3-5	mg	1,095	12,582	159	13,836
POLYNUCLEAR AROMATIC HYDROCARBONS					
Acenaphthene	g	12	214	7	246
Acenaphthylene	g	8	103	N/A	111
Anthracene	g	60	677	7	653
Benzo (A) Anthracene	g	38	642	7	1,032
Benzo (A) Pyrene	g	31	751	N/A	782
Benzo (B) Fluoranthene	g	56	2,022	23	2,121
Chrysene	g	51	1,024	14	1,089
DiBenzo (AH) Anthracene	g	N/A	77	N/A	77
Fluoranthene	g	320	2,829	63	3,212
Fluorene	g	10	250	6	266
Benzo (G,H,I) Perylene	g	124	777	N/A	901
Indeno (1,2,3-CD) Pyrene	g	70	863	N/A	933
Naphthalene	g	152	2,174	377	2,703
Perylene	g	13	N/A	N/A	13
Phenanthrene	g	119	1,970	58	2,147
Pyrene	g	112	1,835	62	2,009
1-Methylnaphthalene	g	37	785	32	855
2-Methylnaphthalene	g	72	1,132	44	1,248

Tcts - Tetra counts (10^12) T - Tonnes kg - kilograms g - grams mg - milligrams
N/A - Not Available, parameter data not available for outfall types with less than 20% detection frequency.

6.0 CONCLUDING STATEMENTS

The results of this study provide a significant amplification of previous studies which have investigated wet weather discharges to the Metropolitan Toronto waterfront. A strong emphasis has been placed on the analysis of trace organic compounds, in addition to conventional water quality parameters and heavy metals. This involved special sample collection and analytical procedures, and the application of non-traditional statistical techniques in the analysis of water quality data sets containing information at or below the analytical detection limit. Contaminant concentrations and contaminant mass loadings have also been provided for bypass of primary effluent at the Main WPCP.

The following summarizes the major statements derived from this study:

Flow Characteristics

- Seasonal (May 1 through October 31) runoff volumes were obtained through computer simulations by the City of Toronto Department of Works and the Environment using the Dorsch Quantity-Quality Simulation (QQS) Model. The predictions were based on the 1980 rainfall distribution which was determined to be representative of historical average conditions for characteristics such as seasonal and event rainfall depth, event duration, event intensity and number of events. Plant data was used to estimate seasonal discharges from the Metro Main WPCP bypass.

- The applicability of the QQS Model predictions for the estimation of volumetric discharges from sewer outfalls was evaluated through comparisons with field measured flow data collected at several sites in this study. Generally, the predicted runoff volumes were found to be within 20 percent of the field measurements.

- The total seasonal (May 1 to October 31) flow volume from outfalls discharging to the City of Toronto waterfront was estimated to be about 5.3 million cubic meters,

which includes 0.3 million cubic meters discharged as bypass of primary effluent from the Metro Main WPCP.

- Geographically, about 48% of the total wet weather flow is discharged to the Toronto Inner Harbour, 31% to the Western Beaches, 17% to Ashbridges Bay and 4% to the Eastern Beaches.

- By outfall type, about 81% of the total wet weather flow is discharged from outfalls which receive combined sewer overflows, 12% from outfalls which receive storm water from separated storm sewers and about 7% from the bypass at the Metro Main WPCP.

- Approximately 56% of the total flow volume is discharged by five sewer outfalls which receive CSOs and the Metro Main WPCP bypass. These discharges are identified with their corresponding relative flow contribution as: TH14 (14%), TH15 (13%), W13 (10%), W2 (7%), Metro Main WPCP bypass (7%) and E11 (5%).

Compilation of Contaminant Database

- Low level detection techniques used in the analysis of trace organic compounds improved the analytical detection limit by a factor of 10 over traditional methods. This resulted in the identification of more priority pollutants and produced higher detection frequencies than reported in previous studies.

- A list of parameters with relatively high detection frequencies has been compiled. The list includes parameters from the following organic contaminant groupings: chlorobenzenes, organochlorine pesticides, and polynuclear aromatic hydrocarbons (PAHs). PAHs were detected more frequently than other trace organic parameters, and detection frequencies generally exceeded 80%.

- Parameters where discharge concentrations are generally in exceedance of applicable receiving water criteria have also been identified for consideration in future regulatory monitoring programs.

- Many toxic parameters found at high frequencies of detection have also been identified by MOEE as candidate substances for bans or phase-outs.

Contaminant Concentration Characteristics

- The statistical relationship between the event mean concentration (EMC) and runoff volumes was evaluated. In general, the EMCs were found to be independent of runoff volume and no significant relationships were identified using linear regression analysis. However, for large events in which significant overflow volumes occurred, data collected at one CSO site (outfall W5) showed that when presented graphically, event mean concentrations for conventional parameters (eg. suspended solids, nutrients and heavy metals) appeared to increase linearly with runoff volume.

- In comparison to storm sewer discharges, average event mean contaminant concentrations measured in discharges from outfalls receiving combined sewer overflows were found to be similar for most parameters. However, significantly higher concentrations were measured in CSO discharges for total phosphorus, most heavy metals, and a few trace organic compounds such as PCBs, lindane, pp-DDD, benzo (b) fluoranthene and chrysene.

- In comparison to sewer discharges, average event mean contaminant concentrations measured at the Metro Main WPCP bypass were significantly higher for nutrients, phenolics and most heavy metals. Concentrations of trace organic compounds were generally similar to those measured in sewer outfalls.

- Average event mean concentrations for all discharges considered in this study were generally in exceedance of Provincial Water Quality Objectives/Guidelines for general chemistry parameters, bacteria and heavy metals. With the exception of dieldrin and PCBs, concentrations of trace organic compounds, which have applicable provincial water quality criteria, were generally lower than Provincial Water Quality Objectives.

- While concentrations of trace organic compounds were generally lower than Provincial Objectives, these and many other parameters for which objectives are not available were found at high frequencies of detection, and have been identified by the Ontario Ministry of Environment and Energy as candidate substances for bans or phaseouts.

Comparison of Contaminant Mass Discharges

- Contaminant mass loadings have been presented by outfall type and geographic region. Contaminant mass loadings for sources considered in this study are highly dependent on flow volume discharge because, for many parameters, concentrations measured in each source are similar.

- Consistent with estimates of flow volumes discharged, contaminant mass loadings from CSO outfalls are generally an order of magnitude higher than those estimated for discharges from storm sewers and the Metro Main WPCP bypass. Similarly, contaminant mass loadings to Toronto Inner Harbour are generally higher than the other three regions (Western Beaches, Ashbridges Bay and Eastern Beaches).

- While the combined volumetric discharge from CSO outfalls was estimated to exceed the discharge from the Metro Main bypass by a factor of 12, contaminant mass loadings from the bypass were found to be similar or exceed CSOs for several parameters including ammonia, total phosphorus, phenolics, cadmium, chromium and silver.

- On a regional basis, estimates of contaminant mass loadings are generally higher for the Inner Harbour followed by the Western Beaches, Ashbridges Bay and the Eastern Beaches. Loadings to the Eastern Beaches are typically an order of magnitude lower than the other regions. Contaminant mass loadings to the Inner Harbour are typically 40 to 60 percent of the total estimated loadings. However, because of significant contributions from the Metro Main bypass, loadings to the Ashbridges Bay area are higher for nutrients, phenolics and some heavy metals.

The distribution of flow volumes and contaminant mass loadings as reported by outfall type and geographic region is continuing to change as a result of ongoing improvements to the City of Toronto sewer system. For example, since initiating this study, the Phase II Eastern Beaches Detention Tank has been constructed and will result in a reduction of flow volumes and contaminant loadings to the Eastern Beaches, and a reduction of contaminant loadings from storm sewers and combined sewer overflows to the waterfront.

Contaminant mass loadings presented in this report represent the seasonal contribution for the period May 1 to October 31. A previous RAP study suggested that these seasonal estimates may represent only about one third of the total annual loading. Consequently, a separate study is being conducted to evaluate seasonal differences in chemical concentrations, discharge flow volumes and contaminant mass loadings.

It should be emphasized that while this report presents a comprehensive analysis of direct wet weather discharges to the City of Toronto waterfront, a comparison between all sources discharging to the waterfront requires consideration of all contaminant discharges including area tributaries. This analysis is being conducted through a separate RAP study.

In addition, while the contaminant concentration and mass loading data presented in this report provides an indication of the potential impact on the nearshore aquatic environment, the degree of actual impact will depend on site specific conditions which include outfall configuration, discharge flow rate, shoreline geometry, lake bathymetry, lake stratification,

lake circulation patterns and the cumulative effect of all waterfront discharges. This can be assessed through computer simulation and a project directed at developing a numerical model to provide water quality and water circulation patterns along the waterfront, has been initiated jointly by the Ontario Ministry of Environment and Energy, Environment Canada, the Municipality of Metropolitan Toronto and the waterfront cities of Etobicoke, Toronto and Scarborough. Once completed, the model will be used to assess the relative impact of all waterfront discharges on the near shore aquatic environment, evaluate options to mitigate the impact of these discharges and assist in establishing priorities for these remedial actions.

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APPENDIX A

Field Program - Flow Datalogger Setups

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UMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM QBase MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM8
3ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD Datalogger setup DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?3
33      ID: 12                 Instrument:  MVP Q-Logger depth, velocity        33
33Comment: loc. W5 CNE grounds at dufferin street                               33
33                                                                              33
33     Probe: Type 2 (5 psi)    Depth: mm     Depth offset:       0.00 mm      33
33Direction: Upstream          Velocity: m/s        Interval:  5 min            33
33                                                   Memory: Wraparound         33
33                                                                              33
33          Equation:  MVP Q = V x A (round pipe)                               33
33              Flow: l/s                                                       33
33                                                                              33
33      Pipe diameter:    1890.00 mm       Operate sampler: Yes                 33
33      Default depth:       0.00 mm         Flow quantity:   20.000K l         33
33   Flow coefficient:       1.00             Sampler mode: High flow           33
33   Default velocity:       0.00 m/s      Threshold depth:    100.00 mm        33
33                                                                              33
33                                                                              33
33                                                                              33
33    Connection: Direct                                                        33
33                                                                              33
33                                                                              33
3@DDDDDDDDDDDD F1/F2-Change ID  F3-Duplicate  ENTER-View options DDDDDDDDDDDDDY3
TMMMMMMMMMMMMM ESC to exit,  to move, Y to select, F10 for Help MMMMMMMMMMMMM>
 Study name: tomoewws
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UMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM QBase MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM8
3ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD Datalogger setup DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?3
33      ID: 14                 Instrument:  MVP Q-Logger depth, velocity        33
33Comment: loc. W6 cowen ave. north of springhurst ave. on east s/w             33
33                                                                              33
33     Probe: Type 2 (5 psi)    Depth: cm     Depth offset:       0.00 cm      33
33Direction: Upstream          Velocity: m/s        Interval:  5 min            33
33                                                   Memory: Slate              33
33                                                                              33
33          Equation:  MVP Q = V x A (round pipe)                               33
33              Flow: l/s                                                       33
33                                                                              33
33      Pipe diameter:     300.00 cm       Operate sampler: Yes                 33
33      Default depth:       0.00 cm         Flow quantity:   25.000K l         33
33   Flow coefficient:       1.00             Sampler mode: High flow           33
33   Default velocity:       0.00 m/s      Threshold depth:     10.00 cm        33
33                                                                              33
33                                                                              33
33                                                                              33
33    Connection: Direct                                                        33
33                                                                              33
33                                                                              33
3@DDDDDDDDDDDD F1/F2-Change ID  F3-Duplicate  ENTER-View options DDDDDDDDDDDDDY3
TMMMMMMMMMMMMM ESC to exit,  to move, Y to select, F10 for Help MMMMMMMMMMMMM>
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UMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM QBase MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM8
3ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD Datalogger setup DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?3
33      ID: 32                 Instrument:  STR Q-Logger depth, velocity        33
33Comment: loc. W13 parkside dr. at garden ave.                                 33
33                                                                              33
33     Probe: Type 2 (5 psi)    Depth: cm     Depth offset:       0.00 cm      33
33Direction: Upstream          Velocity: m/s        Interval:  5 min            33
33                                                   Memory: Slate              33
33                                                                              33
33          Equation:  STR Q = V x A (round pipe)                               33
33              Flow: l/s                                                       33
33                                                                              33
33      Pipe diameter:     300.00 cm       Operate sampler: Yes                 33
33      Default depth:       0.00 cm         Flow quantity:    5.000K l         33
33   Flow coefficient:       1.00             Sampler mode: High flow           33
33   Default velocity:       0.00 m/s      Threshold depth:      5.00 cm        33
33                                                                              33
33                                                                              33
33                                                                              33
33    Connection: Direct                                                        33
33                                                                              33
33                                                                              33
3@DDDDDDDDDDDD F1/F2-Change ID  F3-Duplicate  ENTER-View options DDDDDDDDDDDDDY3
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3ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD Datalogger setup DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?3
33      ID: 31                  Instrument:  STR Q-Logger depth, velocity       33
33Comment: loc. E11 entrance to Greenwood racetrack                             33
33                                                                              33
33    Probe: Type 2 (5 psi)     Depth: mm      Depth offset:       0.00 mm      33
33Direction: Upstream          Velocity: m/s        Interval:  5 min            33
33                                                    Memory: Wraparound        33
33                                                                              33
33           Equation:  STR Q = V x A (rectangular or trapezoidal)              33
33               Flow: l/s                                                      33
33                                                                              33
33      Channel Height:   1820.00 mm       Operate sampler: Yes                 33
33       Default depth:      0.00 mm         Flow quantity:    50.000K l        33
33    Flow coefficient:      1.00             Sampler mode: High flow           33
33    Default velocity:      0.00 m/s      Threshold depth:       80.00 mm      33
33     Width at bottom:   2640.00 mm                                            33
33        Width at top:   2640.00 mm                                            33
33                                                                              33
33     Connection: Direct                                                       33
33                                                                              33
33                                                                              33
3@DDDDDDDDDDDD F1/F2-Change ID  F3-Duplicate  ENTER-View options DDDDDDDDDDDDDY3
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 Study name: tomoewws
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UMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM QBase MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM8
3ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD Datalogger setup DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?3
33      ID: 34                  Instrument:  STR Q-Logger depth, velocity       33
33Comment: loc. TH15 wellington st works yard                                   33
33                                                                              33
33    Probe: Type 2 (5 psi)     Depth: mm      Depth offset:       0.00 mm      33
33Direction: Upstream          Velocity: m/s        Interval:  5 min            33
33                                                    Memory: Wraparound        33
33                                                                              33
33           Equation:  STR Q = V x A (round pipe)                              33
33               Flow: l/s                                                      33
33                                                                              33
33       Pipe diameter:   2410.00 mm       Operate sampler: Yes                 33
33       Default depth:      0.00 mm         Flow quantity:    15.000K l        33
33    Flow coefficient:      1.00             Sampler mode: High flow           33
33    Default velocity:      0.00 m/s      Threshold depth:       70.00 mm      33
33                                                                              33
33                                                                              33
33                                                                              33
33     Connection: Direct                                                       33
33                                                                              33
33                                                                              33
3@DDDDDDDDDDDD F1/F2-Change ID  F3-Duplicate  ENTER-View options DDDDDDDDDDDDDY3
TMMMMMMMMMMMM ESC to exit,  to move, Y to select, F10 for Help MMMMMMMMMMMMM>
 Study name: tomoewws
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UMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM QBase MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM8
3ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD Datalogger setup DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?3
33      ID: 35                  Instrument:  STR Q-Logger depth, velocity       33
33Comment: loc. TH12 simcoe st. and front st.                                   33
33                                                                              33
33    Probe: Type 2 (5 psi)     Depth: cm      Depth offset:       0.00 cm      33
33Direction: Upstream          Velocity: m/s        Interval:  5 min            33
33                                                    Memory: Slate             33
33                                                                              33
33           Equation:  STR Q = V x A (round pipe)                              33
33               Flow: l/s                                                      33
33                                                                              33
33       Pipe diameter:    180.00 cm       Operate sampler: Yes                 33
33       Default depth:      0.00 cm         Flow quantity:     5.000K l        33
33    Flow coefficient:      1.00             Sampler mode: High flow           33
33    Default velocity:      0.00 m/s      Threshold depth:        5.00 cm      33
33                                                                              33
33                                                                              33
33                                                                              33
33     Connection: Direct                                                       33
33                                                                              33
33                                                                              33
3@DDDDDDDDDDDD F1/F2-Change ID  F3-Duplicate  ENTER-View options DDDDDDDDDDDDDY3
TMMMMMMMMMMMM ESC to exit,  to move, Y to select, F10 for Help MMMMMMMMMMMMM>
 Study name: tomoewws
```

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UMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM QBase MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM8
3ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD Datalogger setup DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?3
33      ID: 11                      Instrument:  MVP Q-Logger depth, velocity       33
33Comment: loc. E3 Balsam Ave. south of Fir Ave.                                     33
33                                                                                   33
33     Probe: Type 2 (5 psi)    Depth: mm      Depth offset:       0.00 mm          33
33Direction: Upstream         Velocity: m/s        Interval:  5 min                  33
33                                                    Memory: Wraparound             33
33                                                                                   33
33           Equation:  MVP Q = V x A (round pipe)                                   33
33               Flow: l/s                                                           33
33                                                                                   33
33       Pipe diameter:    1370.00 mm        Operate sampler: Yes                    33
33       Default depth:       0.00 mm          Flow quantity:   10.000K l            33
33    Flow coefficient:       1.00              Sampler mode: High flow              33
33    Default velocity:       0.00 m/s       Threshold depth:      30.00 mm          33
33                                                                                   33
33                                                                                   33
33                                                                                   33
33     Connection: Direct                                                            33
33                                                                                   33
33                                                                                   33
3@DDDDDDDDDDDD F1/F2-Change ID  F3-Duplicate  ENTER-View options DDDDDDDDDDDDDY3
TMMMMMMMMMMMM ESC to exit,  to move, Y to select, F10 for Help MMMMMMMMMMMMM>
 Study name: tomeswws
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UMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM QBase MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM8
3ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD Datalogger setup DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?3
33      ID: 33                      Instrument:  STR Q-Logger depth, velocity       33
33Comment: loc. E5 Glen Manor Dr. and Bonfield Av.                                   33
33                                                                                   33
33     Probe: Type 2 (5 psi)    Depth: mm      Depth offset:       0.00 mm          33
33Direction: Upstream         Velocity: m/s        Interval:  5 min                  33
33                                                    Memory: Wraparound             33
33                                                                                   33
33           Equation:  STR Q = V x A (round pipe)                                   33
33               Flow: l/s                                                           33
33                                                                                   33
33       Pipe diameter:    1500.00 mm        Operate sampler: Yes                    33
33       Default depth:       0.00 mm          Flow quantity:   60.000K l            33
33    Flow coefficient:       1.00              Sampler mode: High flow              33
33    Default velocity:       0.00 m/s       Threshold depth:      70.00 mm          33
33                                                                                   33
33                                                                                   33
33                                                                                   33
33     Connection: Direct                                                            33
33                                                                                   33
33                                                                                   33
3@DDDDDDDDDDDD F1/F2-Change ID  F3-Duplicate  ENTER-View options DDDDDDDDDDDDDY3
TMMMMMMMMMMMM ESC to exit,  to move, Y to select, F10 for Help MMMMMMMMMMMMM>
 Study name: tomeswws
```

APPENDIX B

Contaminant Mass Loading Summaries by Region

TABLE B.1 STORM/CSO/WPCP BYPASS LOADINGS SUMMARY BY REGION

Parameter	Units	STORM				CSO				BYPASS	TOTAL LOADS				
		Western Beaches	Inner Harbour	Ashbridges Bay	Eastern Beaches	Western Beaches	Inner Harbour	Ashbridges Bay	Eastern Beaches	Ashbridges Bay	Western Beaches	Inner Harbour	Ashbridges Bay	Eastern Beaches	Grand Total
GENERAL CHEMISTRY															
Chemical Oxygen Demand	kg	341,660	318,922	469,058	310,955	1,710,115	2,833,923	416,805	71,979	181,304	2,051,775	3,152,845	1,067,167	382,934	6,654,720
Ammonium - tot. filt. react.	kg	12	11	16	11	885	1,466	216	37	7,750	897	1,477	7,982	48	10,404
Nitrates - tot. filt. react.	kg	298	278	409	271	1,032	1,710	252	43	29	1,330	1,988	690	314	4,321
Nitrite - filtered reactive	kg	21	20	29	19	236	391	57	10	6	257	411	93	29	790
Total kjeldahl Nitrogen	kg	624	583	857	568	8,374	13,876	2,041	352	17,992	8,998	14,459	20,890	920	45,267
Phenolics - unfilt. react.	kg	2	2	3	2	15	25	4	1	43	17	27	49	3	96
Total Phosphorus	kg	125	116	171	113	1,902	3,152	464	80	5,121	2,026	3,268	5,755	193	11,243
Total Suspended Solids	kg	36,140	33,735	49,616	32,892	474,704	786,658	115,699	19,980	164,696	510,844	820,393	330,011	52,872	1,714,121
Residue - total	kg	103,257	96,385	141,760	93,977	1,059,976	1,756,544	258,347	44,615	274,724	1,163,234	1,852,929	674,831	138,592	3,829,586
Cyanide - avl. unfil. react.	kg	1	1	1	1	12	20	3	0	25	13	20	29	1	63
Solvent Extractables	kg	623	581	855	567	7,062	11,702	1,721	297	11,003	7,684	12,283	13,579	864	34,410
BACTERIOLOGY															
Escherichia Coliform MF	Tcts	621	580	853	565	23,051	38,199	5,618	970	N/A	23,672	38,779	6,471	1,535	70,458
Fecal Coliform MF	Tcts	802	748	1,101	730	28,045	46,475	6,835	1,180	N/A	28,847	47,224	7,936	1,910	85,917
Fecal Streptococcus MF	Tcts	185	173	254	169	3,405	5,643	830	143	N/A	3,591	5,816	1,084	312	10,803
Pseudomonas Aeruginosa MF	Tcts	2	1	2	1	338	559	82	14	N/A	339	561	84	16	1,000
HEAVY METALS															
Silver	kg	0	0	0	0	6	10	1	0	38	6	10	40	1	57
Aluminum	kg	213	198	292	193	6,015	9,968	1,466	253	1,550	6,227	10,166	3,308	447	20,148
Barium	kg	6	6	9	6	144	239	35	6	111	151	245	154	12	562
Berylium	kg	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cadmium	kg	0	0	0	0	1	2	0	0	4	2	3	4	0	9
Chromium	kg	1	1	1	1	31	51	8	1	104	32	52	113	2	199
Copper	kg	7	6	9	6	136	225	33	6	204	142	231	247	12	632
Iron	kg	430	401	590	391	12,472	20,668	3,040	525	12,975	12,902	21,069	16,605	916	51,492
Mercury	g	6	6	8	6	147	244	36	6	221	153	250	266	12	681
Manganese	kg	24	23	33	22	516	855	126	22	59	540	878	218	44	1,680
Nickel	kg	2	1	2	1	22	37	5	1	17	24	38	25	2	89
Lead	kg	9	8	12	8	162	269	40	7	45	171	277	96	15	559
Zinc	kg	23	21	31	21	369	611	90	16	291	391	632	412	36	1,471

Tcts - Tetra counts (10^12) T - Tonnes kg - kilograms

Note: Bacteriology totals do not include the Main Metro WPCP Bypass

TABLE B.1 STORM/CSO/WPCP BYPASS LOADINGS SUMMARY BY REGION

Parameter	Units	STORM				CSO				BYPASS	TOTAL LOADS				
		Western Beaches	Inner Harbour	Ashbridges Bay	Eastern Beaches	Western Beaches	Inner Harbour	Ashbridges Bay	Eastern Beaches	Ashbridges Bay	Western Beaches	Inner Harbour	Ashbridges Bay	Eastern Beaches	Grand Total
ORGANOCHLORIDE PESTICIDES/CHLOROBENZENES															
Aldrin	mg	8	7	10	7	2,211	3,665	539	93	83	2,219	3,672	632	100	6,623
Alpha-bhc	mg	279	261	384	254	2,772	4,593	676	117	509	3,051	4,854	1,568	371	9,843
Gamma-bhc (Lindane)	mg	156	146	215	142	4,084	6,767	995	172	1,765	4,240	6,913	2,975	314	14,442
Chlordane - alpha	mg	372	347	511	339	4,718	7,818	1,150	199	1,644	5,090	8,165	3,304	537	17,096
Chlordane - gamma	mg	408	381	561	372	4,688	7,769	1,143	197	1,415	5,097	8,150	3,119	569	16,934
Dieldrin	mg	363	339	498	330	4,673	7,744	1,139	197	242	5,036	8,083	1,879	527	15,526
DMDT - Methoxychlor	mg	270	252	371	246	4,393	7,280	1,071	185	69	4,664	7,533	1,511	431	14,138
Endosulfan - Sulphate	mg	94	88	129	86	914	1,515	223	38	17	1,008	1,603	369	124	3,104
Endosulfan - II	mg	62	58	85	57	722	1,197	176	30	69	785	1,255	331	87	2,458
Heptachlorepoxide	mg	21	20	29	19	236	391	57	10	25	257	411	111	29	808
Heptachlor	mg	88	82	121	80	221	366	54	9	17	309	449	192	89	1,039
OP-DDT	mg	322	300	442	293	3,170	5,253	773	133	837	3,492	5,553	2,052	426	11,523
PCB total	mg	1,351	1,262	1,855	1,230	95,236	157,820	23,212	4,008	25,604	96,587	159,082	50,671	5,238	311,578
PP-DDD	mg	147	137	202	134	6,413	10,627	1,563	270	221	6,560	10,765	1,987	404	19,716
PP-DDE	mg	187	174	256	170	3,317	5,497	808	140	2,872	3,504	5,671	3,937	310	13,421
PP-DDT	mg	806	753	1,107	734	12,074	20,008	2,943	508	436	12,880	20,761	4,486	1,242	39,369
Hexachlorobutadiene	mg	8	8	11	8	280	464	68	12	45	288	472	125	19	905
Hexachlorobenzene	mg	32	30	44	29	442	733	108	19	678	474	763	830	48	2,114
Pentachlorobenzene	mg	91	85	125	83	1,459	2,419	356	61	945	1,551	2,504	1,425	144	5,624
Trichlorotoluene 2-6-A	mg	8	7	10	7	-	-	-	-	31	8	7	42	7	63
Trichlorobenzene 1-2-3	mg	8	7	10	7	1,091	1,808	266	46	17	1,099	1,815	294	53	3,260
Tetrachlorobenzene 1-2-3-4	mg	8	7	10	7	855	1,417	208	36	343	863	1,424	561	43	2,891
Tetrachlorobenzene 1-2-3-5	mg	8	7	10	7	147	244	36	6	398	155	251	444	13	864
Trichlorobenzene 1-2-4	mg	30	28	42	28	3,273	5,424	798	138	5,052	3,303	5,452	5,891	165	14,811
Tetrachlorobenzene 1-2-4-5	mg	8	7	10	7	-	-	-	-	699	8	7	709	7	731
Trichlorobenzene 1-3-5	mg	260	242	356	236	4,275	7,085	1,042	180	159	4,535	7,327	1,558	416	13,836
POLYNUCLEAR AROMATIC HYDROCARBONS															
Acenaphthene	g	3	3	4	3	73	121	18	3	7	76	123	28	6	233
Acenaphthylene	g	2	2	3	2	35	58	9	1	0	37	60	11	3	111
Anthracene	g	14	13	20	13	230	381	56	10	7	244	394	83	23	744
Benzo (A) Anthracene	g	9	8	12	8	218	362	53	9	7	227	370	73	17	687
Benzo (A) Pyrene	g	7	7	10	7	255	423	62	11	1	262	429	73	17	782
Benzo (B) Fluoranthene	g	18	17	25	16	687	1,138	167	29	23	705	1,155	215	45	2,121
Chrysene	g	12	11	17	11	348	577	85	15	14	360	588	116	26	1,089
DiBenzo (AH) Anthracene	g	0	0	0	0	26	43	6	1	0	26	44	7	1	78
Fluoranthene	g	76	71	104	69	961	1,593	234	40	63	1,037	1,664	401	110	3,212
Fluorene	g	2	2	3	2	85	141	21	4	6	87	143	30	6	266
Benzo (G,H,I) Perylene	g	29	27	40	27	264	437	64	11	5	293	465	110	38	906
Indeno (1,2,3-CD) Pyrene	g	17	16	23	15	293	486	72	12	6	310	502	100	28	940
Naphthalene	g	36	34	49	33	739	1,224	180	31	377	775	1,258	607	64	2,703
Perylene	g	3	3	4	3	-	-	-	-	0	3	3	4	3	14
Phenanthrene	g	28	26	39	26	669	1,109	163	28	58	698	1,136	260	54	2,147
Pyrene	g	27	25	36	24	624	1,033	152	26	62	650	1,058	250	50	2,009
1-Methylnaphthalene	g	9	8	12	8	267	442	65	11	32	276	450	109	19	855
2-Methylnaphthalene	g	17	16	23	15	385	638	94	16	44	402	654	161	32	1,248

g - grams mg - milligrams

TABLE B.2 PERCENTAGE OF TOTAL LOAD BY REGION

Parameter	Western Beaches	Inner Harbour	Ashbridges Bay	Eastern Beaches
GENERAL CHEMISTRY				
Chemical Oxygen Demand	31%	47%	16%	6%
Ammonium - tot. filt. react.	9%	14%	77%	0%
Nitrates - tot. filt. react.	31%	46%	16%	7%
Nitrite - filtered reactive	33%	52%	12%	4%
Total kjeldahl Nitrogen	20%	32%	46%	2%
Phenolics - unfilt. react.	18%	28%	51%	3%
Total Phosphorus	18%	29%	51%	2%
Total Suspended Solids	30%	48%	19%	3%
Residue - total	30%	48%	18%	4%
Cyanide - avl. unfil. react.	20%	32%	46%	2%
Solvent Extractables	22%	36%	39%	3%
BACTERIOLOGY				
Escherichia Coliform MF	34%	55%	9%	2%
Fecal Coliform MF	34%	55%	9%	2%
Fecal Streptococcus MF	33%	54%	10%	3%
Pseudomonas Aeruginosa MF	34%	56%	8%	2%
HEAVY METALS				
Silver	11%	18%	70%	1%
Aluminum	31%	50%	16%	2%
Barium	27%	44%	27%	2%
Berylium	31%	50%	16%	3%
Cadmium	18%	29%	50%	2%
Chromium	16%	26%	57%	1%
Copper	23%	37%	39%	2%
Iron	25%	41%	32%	2%
Mercury	23%	37%	39%	2%
Manganese	32%	52%	13%	3%
Nickel	27%	43%	28%	3%
Lead	31%	50%	17%	3%
Zinc	27%	43%	28%	2%

Tcts - Tetra counts (10^12) T - Tonnes kg - kilograms

Note: Bacteriology totals do not include the Main Metro WPCP Bypass

TABLE B.2 PERCENTAGE OF TOTAL LOAD BY REGION

Parameter	Western Beaches	Inner Harbour	Ashbridges Bay	Eastern Beaches
ORGANOCHLORIDE PESTICIDES/CHLOROBENZENES				
Aldrin	34%	55%	10%	2%
Alpha-bhc	31%	49%	16%	4%
Gamma-bhc (Lindane)	29%	48%	21%	2%
Chlordane - alpha	30%	48%	19%	3%
Chlordane - gamma	30%	48%	18%	3%
Dieldrin	32%	52%	12%	3%
DMDT - Methoxychlor	33%	53%	11%	3%
Endosulfan - Sulphate	32%	52%	12%	4%
Endosulfan - II	32%	51%	13%	4%
Heptachlorepoxide	32%	51%	14%	4%
Heptachlor	30%	43%	18%	9%
OP-DDT	30%	48%	18%	4%
PCB total	31%	51%	16%	2%
PP-DDD	33%	55%	10%	2%
PP-DDE	26%	42%	29%	2%
PP-DDT	33%	53%	11%	3%
Hexachlorobutadiene	32%	52%	14%	2%
Hexachlorobenzene	22%	36%	39%	2%
Pentachlorobenzene	28%	45%	25%	3%
Trichlorotoluene 2-6-A	12%	11%	66%	11%
Trichlorobenzene 1-2-3	34%	56%	9%	2%
Tetrachlorobenzene 1-2-3-4	30%	49%	19%	1%
Tetrachlorobenzene 1-2-3-5	18%	29%	51%	2%
Trichlorobenzene 1-2-4	22%	37%	40%	1%
Tetrachlorobenzene 1-2-4-5	1%	1%	97%	1%
Trichlorobenzene 1-3-5	33%	53%	11%	3%
POLYNUCLEAR AROMATIC HYDROCARBONS				
Acenaphthene	32%	53%	12%	2%
Acenaphthylene	33%	54%	10%	3%
Anthracene	33%	53%	11%	3%
Benzo (A) Anthracene	33%	54%	11%	3%
Benzo (A) Pyrene	34%	55%	9%	2%
Benzo (B) Fluoranthene	33%	54%	10%	2%
Chrysene	33%	54%	11%	2%
DiBenzo (AH) Anthracene	34%	56%	9%	2%
Fluoranthene	32%	52%	12%	3%
Fluorene	33%	54%	11%	2%
Benzo (G,H,I) Perylene	32%	51%	12%	4%
Indeno (1,2,3-CD) Pyrene	33%	53%	11%	3%
Naphthalene	29%	47%	22%	2%
Perylene	24%	22%	33%	21%
Phenanthrene	32%	53%	12%	3%
Pyrene	32%	53%	12%	3%
1-Methylnaphthalene	32%	53%	13%	2%
2-Methylnaphthalene	32%	52%	13%	3%

g - grams mg - milligrams

APPENDIX C

Estimated Range in Integrated Contaminant Mass Loading Estimates

ESTIMATED RANGE IN INTEGRATED CONTAMINANT MASS LOADING ESTIMATES

Estimates of contaminant mass loadings presented in this report were based on model predicted volumetric discharges for a typical rainfall year and contaminant concentration data collected in this study. These estimates are influenced by several sources of variability, which in this study are associated principally with estimating the total volumetric discharges and those associated with estimating the mean contaminant concentrations.

By using an estimate of the variability associated with predictions of volumetric discharges obtained through numerical simulations and the variability associated with the contaminant data sets, a range in the contaminant mass loadings can be estimated. In this approach, the variability associated with estimating the volumetric discharge volumes is based on comparisons between field measured versus model predicted flow data (Chapter 3.0) and the variability associated with estimating contaminant concentrations defined in this study as the 95% confidence intervals (Chapter 4.0). The confidence intervals used in this analysis are based on data which has been pooled by outfall type (ie. STORM, CSO and BYPASS) over a number of events through the monitoring program. Accordingly, while these estimates incorporate the variability between sites and events they do not incorporate analytical variability associated with the chemical analysis of the compounds.

The estimated ranges are summarized in Table C.1 (eg. low, mean, high), where the mean contaminant mass loadings correspond to those estimates presented in Chapter 5.0 (Table 5.1). The assumed variability in flow and concentration are summarized as follows:

- STORM flow volume estimates - ±20%;
- CSO flow volume estimates - ±50%;
- BYPASS flow volumes estimates - ±50%; and
- contaminant concentrations - ±95% confidence interval.

While there may be site specific discrepancies, the ranges presented above reflect the integrated variability associated with pooled data for all City of Toronto waterfront outfalls.

The low and high estimates of seasonal contaminant mass loadings presented in Table C.1 are typically about 30% and 200% of the mean values, respectively.

TABLE C.1 - ESTIMATED RANGE IN INTEGRATED CONTAMINANT MASS LOADING ESTIMATES

Parameter	Units	Contaminant Loadings		
		Low	Mean	High
GENERAL CHEMISTRY				
Chemical Oxygen Demand	kg	2,843,120	6,654,720	12,492,199
Nitrates - tot. filt. react.	kg	1,402	4,321	10,816
Nitrite - filtered reactive	kg	260	790	1,855
Total kjeldahl Nitrogen	kg	19,478	45,267	80,860
Phenolics - unfilt. react.	kg	29	96	338
Total Phosphorus	kg	4,258	11,243	23,119
Total Suspended Solids	kg	674,804	1,714,121	3,417,458
Residue - total	kg	1,730,347	3,829,586	6,572,071
Cyanide - avl. unfil. react.	kg	21	63	144
Solvent Extractables	kg	12,220	34,410	79,694
BACTERIOLOGY				
Escherichia Coliform MF	Tcts	22,447	70,458	167,750
Fecal Coliform MF	Tcts	27,417	85,917	204,380
Fecal Streptococcus MF	Tcts	3,955	10,803	22,569
Pseudomonas Aeruginosa MF	Tcts	302	1,000	2,486
HEAVY METALS				
Silver	kg	14	57	201
Aluminum	kg	7,746	20,148	41,103
Barium	kg	235	562	1,096
Berylium	kg	0.3	0.9	1.4
Chromium	kg	64	199	483
Copper	kg	239	632	1,355
Iron	kg	19,572	51,492	112,199
Mercury	g	221	681	2,192
Manganese	kg	734	1,680	2,967
Nickel	kg	31	89	128
Lead	kg	239	559	1,027
Zinc	kg	604	1,471	2,926

Tcts - Tetra counts (10 ^ 12) T - Tonnes kg - kilograms

Note: Bacteriology totals do not include the Main Metro WPCP Bypass

TABLE C.1 - ESTIMATED RANGE IN INTEGRATED CONTAMINANT MASS LOADING ESTIMATES

Parameter	Units	Contaminant Loadings		
		Low	Mean	High
ORGANOCHLORINE PESTICIDES/CHLOROBENZENES				
Alpha-bhc	mg	3,453	9,843	22,961
Gamma-bhc (Lindane)	mg	4,962	14,442	35,059
Chlordane - alpha	mg	5,268	17,096	49,753
Chlordane - gamma	mg	4,881	16,934	48,120
Dieldrin	mg	5,418	15,526	34,420
DMDT - Methoxychlor	mg	4,968	14,138	30,852
Endosulfan - Sulphate	mg	1,253	3,104	5,980
Endosulfan - II	mg	804	2,458	6,008
Heptachlorepoxide	mg	294	808	1,735
Heptachlor	mg	492	1,039	2,180
OP-DDT	mg	4,130	11,523	25,934
PCB total	mg	99,225	311,578	792,358
PP-DDD	mg	6,572	19,716	44,954
PP-DDE	mg	3,927	13,421	45,208
Hexachlorobutadiene	mg	309	905	2,079
Hexachlorobenzene	mg	605	2,114	5,976
Trichlorotoluene 2-6-A	mg	41	63	85
Trichlorobenzene 1-2-3	mg	1,219	3,260	6,589
Tetrachlorobenzene 1-2-3-4	mg	1,138	2,891	5,598
Trichlorobenzene 1-2-4	mg	6,346	14,811	26,444
Trichlorobenzene 1-3-5	mg	5,327	13,836	27,686
POLYNUCLEAR AROMATIC HYDROCARBONS				
Acenaphthene	g	77	233	538
Acenaphthylene	g	40	111	237
Anthracene	g	227	744	1,877
Benzo (B) Fluoranthene	g	713	2,121	4,676
Chrysene	g	398	1,089	2,268
Fluoranthene	g	1,079	3,212	7,632
Benzo (G,H,I) Perylene	g	307	906	2,120
Indeno (1,2,3-CD) Pyrene	g	326	940	2,071
Naphthalene	g	774	2,703	7,977
Phenanthrene	g	761	2,147	4,658
Pyrene	g	704	2,009	4,419
1-Methylnaphthalene	g	295	855	1,897
2-Methylnaphthalene	g	423	1,248	2,859

g - grams mg - milligrams